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The Course of Oil

By K. C. SCLATER

Petroleum's Refining Facilities

According to a report of the U. S. Bureau of Mines, there were 547 refineries in the United States at the beginning of this year, the highest number ever recorded in the nation. Of this number 86, or about 16 percent, were not in operation.

Many new refining processes are being developed and much of the recent new construction has consisted of polymerization, alkylation, and solvent-extraction units for the processing of crude oil. Three-fifths of the refineries now in operation are skimming or skimming and cracking plants engaged primarily in the manufacture of gasoline.

What demands are to be made on the refining industry and its present facilities toward national defense are yet problematical. There is every reason to believe, however, that, with one exception, for any demands made upon the industry by the government present refining facilities will be sufficient. The one exception concerns facilities for the manufacture of 100-octane gasoline in quantities that are likely to be required by the government in its national defense program. Although the raw materials for high-octane gasoline are available, the facilities for its manufacture in quantity are lacking. Construction of refining installations for the manufacture of high-octane gasoline in large quantities is therefore expected to be undertaken without delay. There is also likely to be a demand for other products from petroleum, among the most important of which is rubber. Plants are already under construction for the manufacture of synthetic rubber from petroleum. Probably more than any other industry, petroleum finds itself prepared to gear its operations to the program of national defense with a minimum of dislocation to its normal operations.

●

Energy Conservation Equipment

Maintenance of pressure in so-called condensate pools is imperative. Without maintenance of pressure such pools would have a very short producing life and would be failures as industrial ventures because of the low recovery that would be possible. By utilizing the energy of the high-pressure gas it is possible to maintain a pressure in the pool reservoir sufficient to prevent the condensate from liquefying in the sand and so impair and prevent recovery.

By installing a recycling plant the energy of the high-pressure gas in the pool is conserved and valuable liquid petroleum constituents recovered. There are 25 such plants in Texas, and they handle a total of 766 million cubic feet of gas daily. All these plants have been built and put into operation during a period of little more than two years. Of the 766 million cubic feet of gas handled 669 million cubic feet, or 87 percent, is returned to the reservoir under high pressure. The gas is produced from 137 wells and is returned to the formation through 53 injection wells. The remainder of the gas is converted into liquid products, used as fuel, and some is marketed.

Recycling plants comprise perhaps the greatest conservation equipment that the producing branch of the industry has yet adopted. It is also one of the most efficient of producing operations and one that promises to be far-reaching in its influence on future production practice.

●

Federal Commission's Decision

After deliberating for some time on the question of whether the production and gathering of natural gas come under the Natural Gas Act, the Federal Power Commission has decided that these operations are not within its jurisdiction and, therefore, are not subject to the provisions of the Natural Gas Act. Bonafide producers of natural gas and those who gather natural gas for delivery to natural gas utilities and not otherwise engaged in interstate distribution are, by this decision, free from interference by the Federal Power Commission.

This decision of the Federal Power Commission is hailed with satisfaction by the oil industry. It is believed that had the Commission asserted jurisdiction it would have placed all producers of oil and natural gas in one category and might have placed the oil industry under more rigid Federal control than that implied in the Cole Bill. Much of the credit for bringing to the attention of the Federal Power Commission the position of natural gas producers goes to the Independent Petroleum Association of America, who intervened with the contention that the production or gathering of natural gas was not within the Federal Power Commission's jurisdiction. In this instance, alertness in recognizing the implications in an adverse decision to the natural gas producer and its extension to the oil producer, prevented regulation that might have been of serious consequence to the petroleum industry as a whole.

●

Mounting Surplus Stocks

One of the questions that the Interstate Compact Commission will probably take up at its meeting in Oklahoma City next month will be the mounting surpluses of crude and gasoline stocks accruing largely from curtailed foreign shipments, as a result of the war in Europe. Contributing also in smaller measure to the increase of crude stocks is the Illinois production, which is not yet prorated, and is still increasing in daily volume.

Some action will have to be taken by the oil-producing states to reduce the output of crude petroleum, at least until more normal conditions prevail or the demand substantially increases. Unless action is taken and taken soon the industry may be faced with drastic reductions in crude prices, which at this time would be quite unwarranted and a serious set-back.

●

EDITOR'S NOTE: In discussing carbon black here last month the average price of the raw gas used in carbon black manufacture was given as 94 cents; it should have read 9.4 cents.

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« « HIGHLIGHTS IN OILDOM » »

Cannot Split Commission's Orders

The Third Court of Civil Appeals at Austin, Texas, has ruled that courts do not possess the power to invalidate some wells granted under a Railroad Commission order and approve others granted under the same order.

The ruling was given in the case of Humble Oil and Refining Company vs. Tom Potter. Potter had been given an order permitting the drilling of six additional wells on a 9-acre tract. The district court held that four of the wells were improperly granted and two should be allowed. The appellate court ruled all should have been invalidated.

●

Mississippi Extends 40-Acre Spacing Rule

The Mississippi Oil and Gas Board has extended its 40-acre spacing rule to include the following potentially productive acreage: west half of sections 3, 10, 15, 22, and 27; all of sections 4, 9, 16, 21, and 28-10n-3w; all of sections 5, 8, 17, 20, and 29-10n-2w; all of sections 33, 34, 35, 36, 25, 26, 27, and 28-11n-3w, and all of sections 29, 30, 31, and 32-11n-2w.

The action was caused by the successful completion of the Slick-Urschel Oil Company's No. 7 Slick, in CSW SW of 36-11n-3w, which gave a slight northerly extension to the producing limits of the Tinsley Dome field, Yazoo County. The well flowed 90 bbl. per hour through 22/64-in. tubing choke from the Eutaw (Blossom) formation at 5442 ft., a new horizon for the Tinsley area. The well logged 17 ft. of saturated oil sand and is one of the best wells completed in the field.

●

Pennsylvania Crude Oil Prices Reduced

The Joseph Seep Purchasing Agency of the South Penn Oil Company recently announced a reduction of 25 cents a bbl. in the price of Pennsylvania grade crude oil. New prices are: Bradford-Alleghany, $2.25 per bbl.; Southwest Pennsylvania Pipe Line, $1.90, and Eureka, $1.84. No change was made in Corning grade.

The reduction in prices was regarded as due to lower prices for lubricating oils for which Pennsylvania grade crude oil is especially desirable.

●

Development of Petroleum In Slovakia

Slovakia has granted to the Deutsche Erdöl A. G. for a period of ten years the right to develop the oil field of Gbely. The production of this field has been less than 100,000 bbl. per year; only in 1922 with an output of 115,000 bbl. was this average exceeded. Development of the field will be accelerated, it is announced, in order to meet domestic requirements, which are estimated at 335,000 bbl. per year.

●

Seven Shut-down Days For Texas

An amended shutdown order by the Texas Railroad Commission, on July 5, provided for closing all wells two additional days each month during July and August. The original order shut down fields five days each month, which means there will be seven days during each of the two months when no oil will be produced. Commissioner Jerry Sadler said the additional closings were necessary to prevent waste.

Oil Operators Not Affected By Gas Act

The Federal Power Commission has ruled that provisions of the natural gas act do not apply to sales of gas made by oil producers or gatherers not otherwise engaged in the gas business. This decision is of importance to the oil industry because it will relieve oil operators who sell gas from their wells from compliance with the natural gas act, under which the Commission would have had full control of their operations.

●

Action Near On Pollution Bill

Final action appears to be near on the federal pollution bill. The House of Representatives is to be asked shortly to issue instructions to its members of the conference committee, which has been trying to adjust the differences between the senate and house versions of the Barkley Bill, it has been learned by the Independent Petroleum Association of America.

The Barkley Bill, passed originally by the senate, provides for administration by a division of the public health service and provides for coöperative action with local and state authorities for elimination of waste disposal into waterways. It was supported by industries, including the oil industry, as a reasonable approach to the problem.

After passing the senate, it was amended in the house to include the provision by Representative Mundt of South Dakota that after date of enactment no "new sources of pollution" shall be discharged into the navigable streams and their tributaries unless approval be given by the administrative division. Such discharge would be declared to constitute a public and common nuisance and would be subject to action by the government or by private persons who might allege damage.

Thus, a new oil well would constitute a new source of pollution.

After passage by the house, the bill went to the conference committee of the house and senate.

●

Ickes Claims More Oil Land For U. S.

Secretary of the Interior Ickes has directed the general land office to take title to section 16 of the Elk Hills Naval Oil Reserve in Kern County, California, for the United States. The property has been under control of private interests.

Although oil production has not yet been discovered in the area, its particular potentiality lies in the fact that section 16 is within a few miles of section 36, which the interior department has characterized as "one of the most valuable square miles of oil land in the world." Ickes took over section 36 for the government a few months ago after a long court battle that resulted in a decision to the effect that title belonged to the United States and directed the former operator, the Standard Oil Company of California, to pay the government $7,138,297 damages for oil it had extracted.

In taking title to section 16 Ickes rejected the appeal of the General Petroleum Corporation of California, Thomas A. O'Donnell, and Hamer I. Tupman, who had protested that they were entitled to the property through acquisition from the State of California. Ickes upheld the findings of the general land office that because section 16 was known to be mineral in character at the time the official survey was accepted in 1903, the area was not covered by the federal school land grant under which the section originally was obtained by California.

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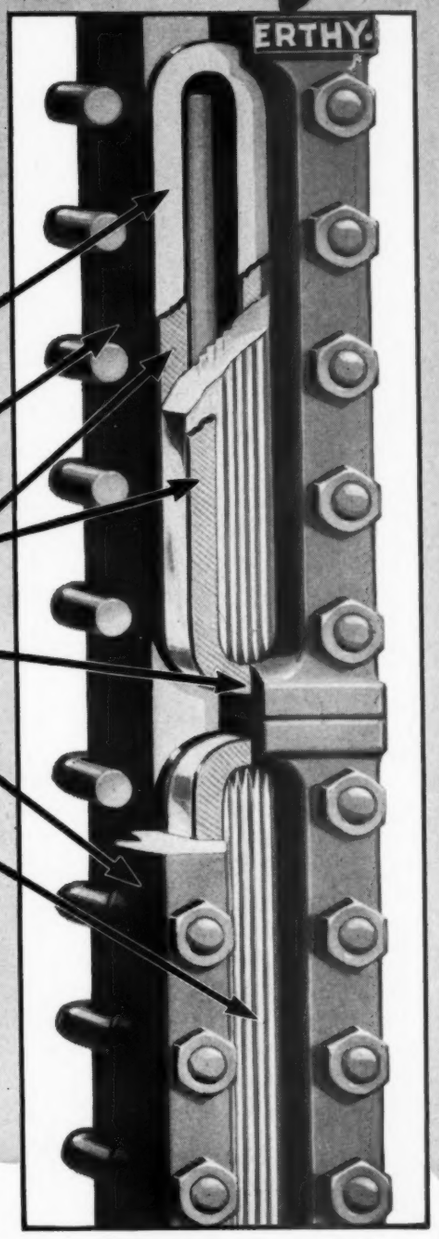

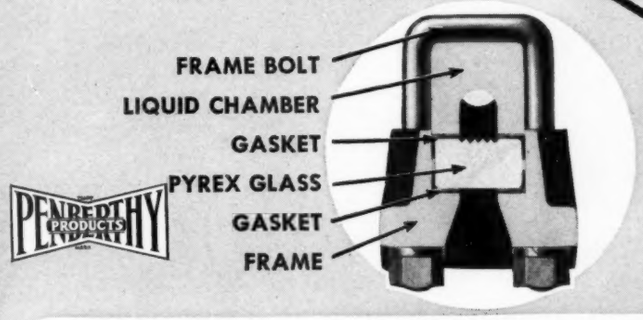

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Major Pipe Line Activities

PHILLIPS PETROLEUM COMPANY has applied to the Federal Power Commission for permission to construct an 887-mile natural gas pipe line from Sherman County, Texas Panhandle, to Milwaukee, Wisconsin.

The trunk line would extend across parts of Texas, Oklahoma, Kansas, Missouri, Iowa, Illinois, and Wisconsin, with laterals extending to distribution companies and industrial consumers. The gas would be sold at wholesale to distributors serving markets in Milwaukee and in northern Wisconsin.

The application was filed by the Independent Natural Gas Company, a wholly owned subsidiary of the Phillips Petroleum Company. The applicant proposes to create another corporation to which the certificate applied for would be issued.

The estimated initial construction cost is $28,698,000, to be financed through a capitalization of $12,000,000 and a long term security issue of $18,000,000.

According to the application, natural gas is not now being used for any purpose in southern Wisconsin; however, the proposed line would cross the pipe-line systems of Northern Natural Gas Company, Panhandle Eastern Pipe Line Company, Natural Gas Pipeline Company of America, and would also cross areas now being served with natural gas by some of these companies.

The application revealed the fact that Phillips Petroleum Company now holds under oil and gas lease 224,266 acres of proved gas properties in the Texas Panhandle area, in which the natural gas reserves are estimated to be 2,800,000,000,000 cu. ft. The company also holds title to 150,768 acres in the Hugoton field, Kansas, with estimated reserves of 990,000,000,000 cu. ft. In addition, the company holds contract for the purchase of natural gas from other leases in the Texas Panhandle, it was stated.

The proposed pipe line would serve companies in Wisconsin having 274,505 domestic consumers and operating in an area with a total population of 1,356,218.

●

Gulf Refining Company, Pipe Line Department, is to lay a 6-in. line from the K.M.A. field, Wichita County, Texas, to Burkburnett, Texas, a distance of 18 miles. The new line will replace the company's old line, which extended from K.M.A. field to Burkburnett via Electra. The line will originate at a point near the center of the Waggoner ranch properties north of the Wichita River.

●

The Kansas Pipe Line and Gas Company is laying 25 miles of pipe line from Cambridge to McCook, Nebraska, with laterals to Indianola and Bartley. The Aksarben Natural Gas Company has purchased the artificial-gas distribution system in McCook and will change over to natural gas as soon as the new pipe line is completed.

Tuscarora Oil Company, Ltd., has completed the laying of 27 miles of 8-in. oil line from Gardenville to Barto, Pennsylvania. The line was constructed by the Superior Construction Company, with the welding contracted by H. C. Price Company.

●

The Northern Natural Gas Company has been authorized by the Iowa Commerce Commission to lay a feeder line from Ogden, Iowa, to Ames, Iowa, about 20 miles. The line will be 10 in. diameter and will connect with the company's trunk system at Ogden. Consumers at Boone, Iowa, as well as at Ames, will be served by the new construction.

●

The Panhandle Eastern Pipe Line Company has elaborated on its recent announcement of plans to construct 105 miles of loops to its main line. J. D. Creveling, president of the company, states the project will involve an expenditure of $2,800,000 and will be financed from present working capital. He states further that the project is to provide additional facilities for the company's growing market requirements.

The new construction work will include the installation of 24-in. line adjacent to existing stations as follows: Liberal, Kansas, 7.57 miles; Greensburg, Kansas, 8.06 miles; Haven, Kansas, 8.25 miles; Olpe, Kansas, 8.29 miles; Louisburg, Kansas, 7.89 miles; Houstonia, Missouri, 6.06 miles; Centralia, Missouri, 6.13 miles, Pleasant Hill, Illinois, 12.94 miles; Glen Arm, Illinois, 16.40 miles; and Tuscola, Illinois, 23.79 miles. The installation at Tuscola will be of 20-in. pipe.

New pumping equipment will consist of the addition of a 1300-hp. unit at Sneed, Texas, and the erection of a new 4000-hp. station near the Oklahoma-Texas line.

Line pipe will be supplied by the National Tube Company.

●

The Atlantic Refining Company has started construction of a new terminal at Fort Mifflin, on the Delaware River, for the reception of tanker shipments of crude oil, chiefly from the Texas oil fields. Completion is scheduled for late in the fall.

The dock structure at the new terminal will be of concrete and will be capable of accommodating simultaneously three of the oil company's new 550-ft. tankers. Crude petroleum will be discharged from the tankers into four shore tanks having a capacity of 80,000 bbl. each. From the new terminal the oil will be pumped through two 16-in. pipe lines to the company's refinery at Point Breeze on the Schuylkill River, a distance of about five miles.

Offices of the company's marine department will be located at the Fort Mifflin terminal. In addition facilities will be provided for storing and provisioning the ships, for repairs, and for the accommodation of officers and seamen. Most of the docks at the Point Breeze refinery will continue to be used by the company's smaller tankers, but the larger oil carriers will discharge their cargoes at Fort Mifflin.

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Activities in the Oil Fields

SOUTHEASTERN Nebraska appears to have obtained its third oil pool, No. 1 Ogle of the Uhri Oil Company, a wildcat in the NE NW SE SE of 9-1n-14e, having swabbed at the rate of 300 bbl. per day after acidizing in the Hunton lime. The well is approximately 10 miles west of Falls City in Richardson County.

The Hunton lime was penetrated at a depth of 2258 ft. and drilled to 2260 ft. Five-inch casing was run and set at 2256 ft., and when the plug was drilled-out the hole filled 1400 ft. with fluid, two-thirds of which was oil.

●

Rowan and Nichols Oil Company's wildcat No. 1 Gilvic Hubbard, near Rowan, Brazoria County, Texas, has been completed at a depth of 8538-54 ft., producing 190 bbl. of 40.5-gravity oil in 24 hours through ⅛-in. choke. The test had been drilled to a total depth of 10,010 ft.

●

Mid-Continent Petroleum Corporation has obtained good evidence of oil in three zones in its No. 1 W. Ferguson, NE SW of 18-7-8, eastern Seminole County, Oklahoma, and the operator seems confident a new field will be opened.

The test penetrated the Gilcrease formation at a depth of 3190 ft. An excellent showing of oil was had in this sand. Drilling deeper to the Wapanucka, at a depth of 3418 ft., a well-saturated sand was found. The Cromwell sand was penetrated at 3443 ft. and it also was found to be well saturated with oil.

The well was drilled to a total depth of 3475 ft. When tested it produced both from the Wapanucka and Cromwell, and the operator believes a nice well also could be had from the Gilcrease sand.

Amerada Petroleum Corporation has opened a new Canyon lime oil pool in northern Wilbarger County, Texas, with its No. 1 Goodpasture, 12 miles northwest of Vernon. Production is through 80 casing perforations from 3230 ft. to 3252 ft. On an initial test the well flowed 241 bbl. of oil in 8 hours and 20 minutes through tubing. On a second test it flowed 150 bbl. in 5½ hours through ½-in. tubing choke, and on a third test 91 bbl. in 2 hours and 50 minutes through ¾-in. tubing choke. It was then choked to 64 bbl. every 4 hours, using ¼-in. choke.

●

Cities Service Oil Company got a good showing of oil in its No. 1 Ray, in NE NW SE of 32-5-20w, which may result in a new pool for Phillips County, Kansas. Casing was set at 3400 ft. to make a test.

The formation is believed to be either the Lansing-Kansas City or Arbuckle lime. Nearest commercial production is in the Bow Creek pool, 17 miles to the east.

●

Pure Oil Company has two pool-opening wells in Illinois. No. A-1 Raphael Bergbower, CE½ NE SE of 16-6n-10e, Jasper County, 3 miles north of the Boos pool, was completed as a pumping well after the McClosky lime was acidized. No. 1 Robert J. Macklin, in the northeast corner of Bedford Township, Wayne County, began flowing after acid treatment of the McClosky lime at a depth of 3036 ft.

●

Republic Petroleum Company has completed a wildcat well in Section 18-32-23 of Kern County, California, in the Midway-Sunset district. The well gauged 350 bbl. of oil per day and 300,000 cu. ft. of gas.

AVERAGE CRUDE OIL PRICES

California	
Kettleman Hills	$1.12-1.38
Playa Del Rey	.65-1.08
Coalinga	.60- .82
Wilmington	.64-1.14
Montana	.90-1.10
Wyoming	.35-1.30
Colorado	.90- .98
New Mexico	.53- .95
Texas	
North Central	.71-1.03
Panhandle	.67- .96
West Texas	.53- .95
Gulf Coast	.86-1.28
Darst Creek	.96
East Texas	1.10
Talco	.65
Kansas	.60-1.10
Oklahoma	.60-1.10
Arkansas	.73-1.05
Louisiana	
Rodessa	$1.05
Gulf Coast	.79-1.28
North Louisiana	.73-1.05
Illinois	.95-1.05
Kentucky	.90-1.10
Indiana	.95
Ohio	
Lima	.90
Michigan	.74-.97½
Pennsylvania	
Bradford	2.25
Southwest	1.90
Eureka	1.84
Corning	1.12
Canada	2.10-2.17

DAILY AVERAGE CRUDE OIL PRODUCTION

Data Supplied by A.P.I.

(Figures in bbl. of 42 gal. each)

	[1]B. of M. Calculated Requirements (July)	Week Ended June 29, 1940	Week Ended June 1, 1940	Week Ended July 1, 1939
Oklahoma	403,900	[2]420,450	422,350	451,950
Kansas	159,400	[2]183,100	158,850	169,100
Nebraska		[2] 150	100	
Panhandle Texas		61,250	67,450	69,000
North Texas		93,650	104,550	86,200
West Central Texas		30,650	32,550	32,500
West Texas		206,400	236,750	218,900
East Central Texas		72,600	79,050	92,300
East Texas		298,300	396,600	372,800
Southwest Texas		206,300	219,350	225,500
Coastal Texas		211,350	228,250	214,950
TOTAL TEXAS	1,339,400	1,180,500	1,364,550	1,312,150
North Louisiana		68,200	70,100	71,650
Coastal Louisiana		219,550	237,950	199,600
TOTAL LA.	278,100	287,750	308,050	271,250
Arkansas	67,400	72,350	71,900	59,000
Mississippi	9,700	[2] 9,650	9,350	
Illinois	402,300	517,050	449,600	245,200
Indiana	9,000	[2] 13,250	11,900	
Eastern (not incl. Ill. and Ind.)	94,100	91,700	98,900	98,200
Michigan	61,600	56,400	59,150	68,600
Wyoming	80,600	79,300	72,200	67,000
Montana	18,100	19,850	17,900	15,900
Colorado	4,800	3,950	3,300	4,050
New Mexico	106.100	105,100	107,350	106,600
TOTAL EAST OF CALIFORNIA	3,034,500	3,040,550	3,155,450	2,869,000
California	593,900	599,000	593,600	594,000
TOTAL U. S.	3,628,400	3,639,550	3,749,050	3,463,000

[1]These are Bureau of Mines' calculations of the requirements of domestic crude oil based upon certain premises outlined in its detailed forecast for the month of July. As requirements may be supplied either from stocks, or from new production, contemplated withdrawals from crude oil inventories must be deducted from the Bureau's estimated requirements to determine the amount of new crude to be produced.

[2]Oklahoma, Kansas, Nebraska, Mississippi, and Indiana figures are for week ended 7 a. m., June 26.

Great Pioneers

PENNSYLVANIA 1675-1690

Although no authentic record has been preserved of William Penn's Indian Treaty, negotiated under the Shackamaxon elm, some time between 1675 and 1690, historians consider it "the most glorious in the annals of the world." Penn's liberal views on government and social freedom made Pennsylvania the largest and most successful of the proprietary colonies. Pennsylvania, second state to join the Union, was admitted on December 12, 1787.

● Oil producers occupy a place of extreme importance in the pioneering and developing of Dowell chemical service for oil and gas wells.

Working in close harmony with leading oil men, Dowell perfected numerous products and services which, today, are accepted as an integral part of production procedure.

Producers are assured that Dowell's experience and all the facilities at its command will continue to be devoted to solving the problems which hinder economical production.

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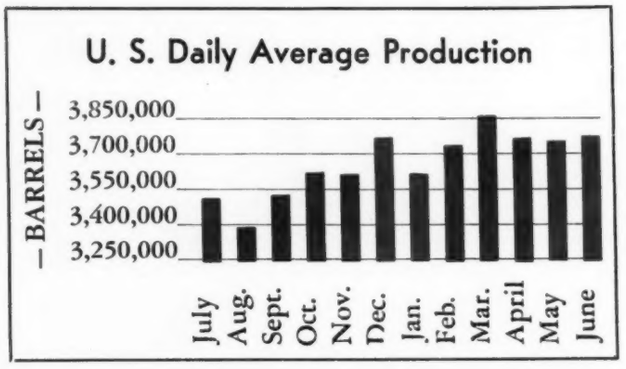
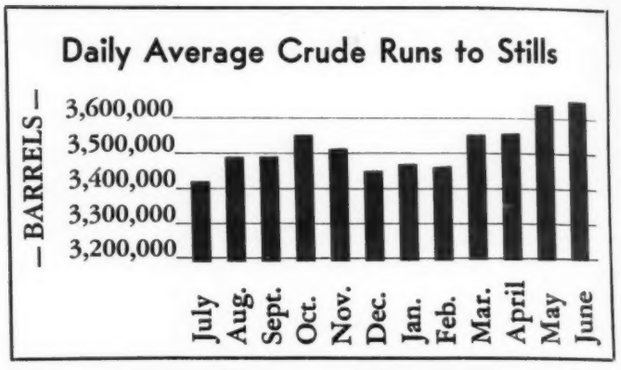
Look to

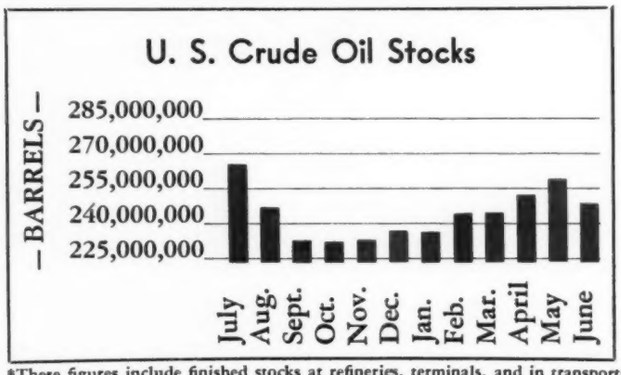
DOWELL

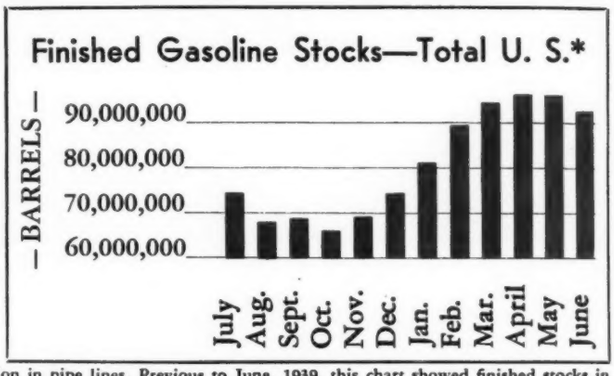
FOR OIL AND GAS WELL CHEMICAL SERVICE

Petroleum Statistics and Field Activities









*These figures include finished stocks at refineries, terminals, and in transportation in pipe lines. Previous to June, 1939, this chart showed finished stocks in refineries only. Above statistics by the American Petroleum Institute.

Summarized Operations in Active Fields for June, 1940

Fields	Completions	Producers	Rigs	Drilling Wells	Depth of Production	No. Casing Strings	Gravity of Oil	Type of Tool Used
Texas								
East Texas	19	19	2	7	3500-3700	2	40	Rotary
Duval County	21	15	6	15	1554-2900	2	22	Rotary
Ector County	62	59	20	48	3675-4377	2 and 3	32-36	Rot.-Cab.
Panhandle	66	62	22	75	1700-3900	2	40	Rotary
Refugio County	8	7	2	4	4900-5900	2	38	Rotary
Nueces County	19	15	2	5	3922-5878	2 or 3	21-54	Rotary
K. M. A. Field	40	37	15	42	3730-3935	2	42-43	Rot.-Cab.
Oklahoma								
Fitts Pool	13	10	2	6	1800-4488	2 or 3	38	Rotary
Kansas								
Russell County	50	42	9	24	2926-3435	2 and 5	32-37	Rot.-Cab.
Rice County	21	15	7	23	3222-4085	2 and 5	42-48	Rot.-Cab.
Barton County	26	16	5	22	3290-3518	2	39-42	Rot.-Cab.
Illinois								
Central Illinois	422	369	368	169	1425-4100	2	36-38	Rot.-Cab.
New Mexico								
Lea County	32	29	16	40	3150-4030	3	30-34	Rot.-Cab.
California								
Kettleman Hills	1	1	1	8	8300-8730	3 or 4	40	Rotary
Wilmington	19	19	22	18	3500-4000	2 and 3	18-20	Rotary

Field Activities by States for June, 1940

State	Completions		Producers		Locations		Rigs		Drilling Wells		Production, 1939 (In Barrels)
	June	May	June	May	June	May	June	May	June	May	
Arkansas	14	14	11	9	12	18	5	4	30	29	21,266,994
California	99	137	90	126	74	131	114	83	191	180	224,336,682
Colorado	....	....	....	....	....	....	2	2	29	25	1,402,599
Illinois	422	346	369	299	411	490	368	378	169	174	92,915,620
Indiana	50	33	25	11	....	....	9	7	64	63	1,426,000
Kansas	218	204	172	151	130	234	40	45	238	249	59,952,340
Kentucky	48	66	16	59	....	....	7	8	88	81	5,611,500
Louisiana	182	159	142	131	130	221	35	43	181	189	94,110,736
Michigan	106	104	62	60	92	101	44	54	161	172	23,185,203
Mississippi	23	27	7	12	....	....	7	8	32	29	102,918
Montana	25	22	19	22	....	....	6	5	43	41	5,901,058
New Mexico	52	55	40	46	31	72	24	26	129	138	37,453,117
New York	95*	95*	95*	94*	....	....	11	20	67	73	5,105,000
Ohio	74*	95*	50*	75*	....	....	58	57	199	171	3,157,500
Oklahoma	206	188	138	122	105	188	45	55	290	309	156,421,939
Pennsylvania	188*	288*	181*	285*	....	....	....	....	....	....	17,342,500
Tennessee	....	1	....	0	....	....	....	....	....	....	....
Texas	953	967	745	743	733	1365	402	411	1295	1387	485,847,999
West Virginia	50	51	42	43	68	....	14	19	120	99	3,556,500
Wyoming	8	8	7	7	....	....	11	12	62	59	21,408,478
Total	2813	2860	2211	2295	1786	2820	1202	1137	3388	3468	1,260,504,683

*Includes water-intake and pressure wells.

Activities in Refining

Percent Refining Capacity Operated

Western Division, 66.0 Percent **Central Division, 81.4** **Eastern Division, 88.5 Percent**

HUNT OIL COMPANY has begun operating its new recycling plant in the Long Lake field, Texas. The plant has a daily capacity of 50,000,000 cu. ft. This is the fourth recycling plant for the field and the sixth for Anderson County.

●

The Bell Oil and Gas Company has announced extensive additions and improvements to its refinery at Grandfield, Oklahoma, and to the Ben Franklin refinery at Ardmore, Oklahoma.

The Grandfield plant has completed the revamping of its straight-run distillation equipment, including the enlargement of its pipestill and installation of new burners. The capacity of the No. 1 pipestill has been increased to 4000 bbl. per day. New pumps also have been installed.

A new firing system has been installed on the Dubbs cracking unit, and the vapor-recovery system has been remodeled. A centrifugal hot-oil pump is being installed to serve the unit.

At the Ben Franklin refinery a complete new treating system has been installed, which has improved the quality of the gasoline manufactured and reduced the amount of chemicals required in the treating process.

●

Paul H. Hewitt of Longview, Texas, has announced plans to construct a 50,000-cu. ft. recycling plant in the Joaquin area of Shelby County, Texas. The plant is expected to cost $250,000 and Hewitt stated an additional $250,000 would be spent to develop gas reserves.

●

Warren Petroleum Corporation has announced plans to erect a natural gasoline plant in the Salem-Lake Centralia field, Illinois. Gas will be taken from wells of the Magnolia Petroleum Company, Shell Oil Company, Inc., Ohio Oil Company, John R. Mitchell, W. C. McBride, and others.

The plant, in addition to manufacturing natural gasoline, will produce propane and butane.

The Anglo-Albertan Oil Refinery plans to erect a tar-sand extraction plant and refinery in the Waterways area of Northern Alberta, Canada, it has been announced by Charles Gower, president and general manager. The plant will have a capacity of 600 bbl. per day and will cost approximately $100,000.

●

H. L. Hunt, independent operator of Dallas, Texas, is heading a group of operators who propose to erect an $18,000,000 recycling plant in the Cotton Valley field, Louisiana.

The plant would have a capacity of 150,000,000 cu. ft. of gas per day, producing approximately 10,000 bbl. of gasoline.

Expense of the project would be borne prorata by the operators, Hunt Oil Company, Ohio Oil Company, Magnolia Petroleum Company, United Gas Pipe Line Company, Stanolind Oil and Gas Company, Oliphant Oil Company, and North American Oil Company.

Gas-distillate is produced in the Cotton Valley field from the 8500-ft. level in the Lower Marine series.

●

Continental Oil Company has completed construction of a thermal polymerization unit at its Wichita Falls, Texas, refinery. The plant is connected to the company's principal natural gasoline plant in the K.M.A. field by a 20-mile, 4-in. pipe line. Capacity of the new unit, which also includes facilities for stabilizing raw natural gasoline, is 2500 to 3000 bbl. per day including charging stock from the cracking units.

●

Derby Oil Company has under construction at its Wichita, Kansas, refinery a 2500-bbl. capacity Perco copper sweetening unit. The unit is being installed under license of Perco, Inc., and is of the solid-process type for treatment of refinery straight-run gasoline.

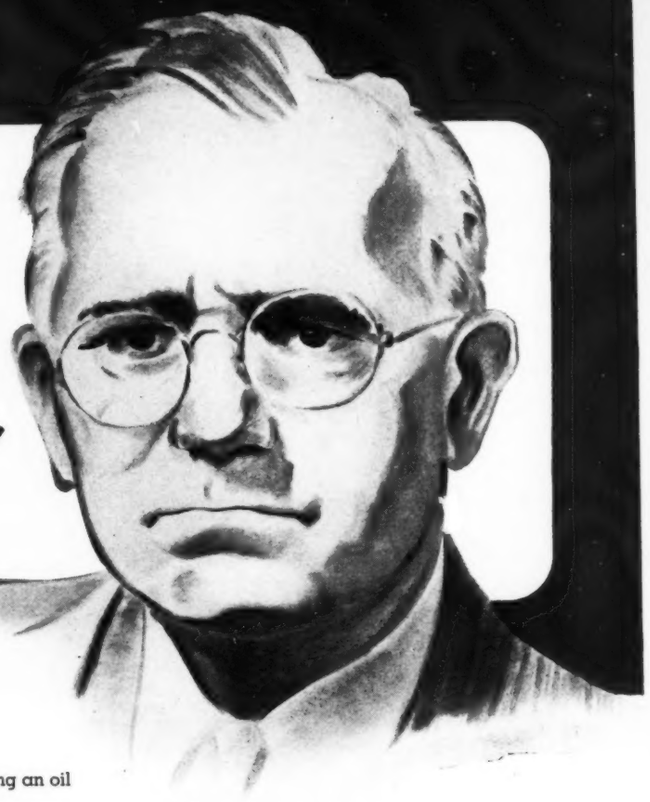
The announcement was made by F. W. McCurry, vice-president in charge of manufacturing of the Derby Oil Company.

Crude Runs to Stills, Gasoline, Gas and Fuel Oil Stocks
Week Ended June 29, 1940
A.P.I. Figures
(Figures in thousands of bbl. of 42 gal. each)

DISTRICT	Percent Potential Capacity Reporting	Daily Average Crude Runs to Stills	Percent Operated of Total Capacity Reporting	Total Motor Fuel Stocks	Total Gas and Fuel Oil Stocks
East Coast	100.0	561	87.2	23,043	19,243
Appalachian	91.0	123	86.6	3,600	848
Ind., Ill., Ky.	90.2	615	91.8	15,960	6,989
Okla., Kans., Mo.	76.9	283	87.6	7,129	3,361
Inland Texas	59.6	112	67.1	1,878	1,708
Texas Gulf	85.3	823	90.0	14,154	10,364
Louisiana Gulf	97.6	143	89.4	2,744	2,228
No. La. and Ark.	51.5	38	73.1	544	738
Rocky Mountain	55.5	42	63.6	1,377	739
California	87.3	500	68.5	17,673	88,038
Reported	85.3	3,240	83.8	88,102	134,256
Estimated Unreported	.....	385	.....	7,040	3,820
*EST'D TOTAL U. S. JUNE 29, 1940	.....	3,625	.....	95,142	138,076
*EST'D TOTAL U. S. JUNE 22, 1940	.....	3,690	.....	97,276	137,357
U. S. B. OF M. *JUNE 29, 1939	.....	**3,490	.....	80,418	144,307

*Estimated Bureau of Mines' basis.
**June, 1939, daily average.

Now we buy INSURANCE *by the foot!*



It used to be we had no way of protecting ourselves in developing an oil well. We'd lay fifty or a hundred thousand on the line for drilling costs and were never sure that mechanical difficulties wouldn't ruin the production of the well before we even got our investment back.

But once safely in the oil sand we've found a way to reduce our risks. Now we insure our well investments against unforeseen production emergencies by using SECURALOY equipment throughout the producing zones. If we run into trouble we don't worry about risky fishing, cutting or washover jobs to get the liner and accessory equipment out. We just drill up the SECURALOY, circulate the chips out of the hole and there's our well —clean and ready for re-development. It's the cheapest—*and best*—insurance we've found yet!

INSURE YOUR WELL WITH

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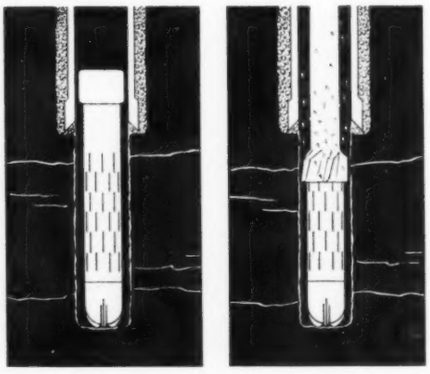
Here's One Way SECURALOY Protects Us...

In completing a well we always use a SECURALOY Liner or Screen opposite the producing zone. Since we don't have to allow for possible wash-over operations, we can use larger liners than otherwise feasible, getting greater drainage area and room for bigger, more efficient pumps. That cuts our production costs substantially.

If, after long production, the perforations get clogged with sand—and washing operations are no longer effective—we simply drill up the liner, scrape the walls to expose fresh formation, and set a new SECURALOY Liner. Except for the natural depletion of the sands, the well is good as new, giving us *complete* oil recovery.



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P 420.12

THE Petroleum Engineer

JULY, 1940

A PETROLEUM ENGINEER FEATURE

Drilling Time Studies as an Aid in Providing Accurate Knowledge of Formations

Equipment for gathering data need not be elaborate—drilling speed is influenced by changes in formation and often is a valuable check on accepted methods of logging.

By H. LEE FLOOD
Associate Editor

WITHOUT attaching any great importance to its use, a knowledge of the relative time required to drill different types of formations has been an index of conditions underground to the driller for many years. Usually the differences were expressed only as "easy" or "hard" drilling and no great significance was connected with the variations. At least no effort was made to employ the information gained in drilling one well as a guide for the drilling of adjacent wells.

In recent years, particularly the last year or two, close attention has been focused on the value of recording the relative speeds of drilling and the entire subject has been dignified by being called "drilling time studies." Even though this term should not convey the impression of being a highly complicated procedure, the fact remains that many drillers and drilling contractors have shied away from drilling time studies because they believe it involves an elaborate procedure and complicated equipment in order to collect the required data.

Drilling Time Studies Need Not Be Complicated

The present purpose is to clarify this misconception and to point out that studies of drilling time need not involve more than an additional routine imposed upon the driller—the mere matter of recording the elapsed time required to drill a given number of feet of hole. The usual procedure is to note the time required to drill 2, 5, or 10 ft. of hole. Readings taken at these intervals usually result in a drilling time log of sufficient accuracy to disclose information concerning the formations drilled and serve as a reliable check on cores taken periodically or on the results of electrical logs.

Of course, instruments are now available that facilitate the recording of rate of penetration automatically. These instruments have an unquestioned advantage over the driller's record, principally because the record is made continuously without requiring the driller to remember to jot down the necessary data. It has been suggested that a rate of penetration recorder has greatest value as a "check" on the activity of the drilling crew. This attitude should be discouraged because the true value of the data—whether manually or automatically recorded—is in the additional information given to the well owner concerning the conditions of his well, and not in its function as a "policeman."

Accuracy of Drilling Time Studies

Aside from the implied objections that drilling time studies are unduly complicated and expensive to make, there has been some doubt of the value to be derived from such studies when made.

Some who have never analyzed time studies of this type have argued that it is of little value to record the time required to drill, say, from 3850 to 3855 ft. in a given well because that information would be of little use in another well. Keeping in mind that the relative drilling time per ft. is, after all, comparative, usually, in only a constricted area, as in a given field, it is always a source of interest to observe the manner in which studies of drilling time will correlate from well to well.

Time studies of drilling are not new, by any means. Many companies have been employing this additional information to good advantage for several years. It requires only a few minutes of study of some of the results that have been attained by these pioneers in this type of analytical procedure for even the most skeptical to be convinced that the method is worth a try.

Engineers and drillers who have made drilling time studies a part of their routine drilling procedure have, in many instances, been able to formulate rather definite "rules-of-thumb"

concerning the potential production of specific formations based entirely upon the time required to drill through them. For example, in one area the drilling superintendent of one large company is able to say that a formation that drills slower than 10 min. per ft. will be non-productive and that faster drilling times represent rather definite assurance that a commercial well will result. It seems unnecessary to qualify this statement by saying that, of course, this rule applies only to formations in which definite evidence of oil is observed.

Drilling time studies are not, however, restricted only to depths at which production is expected. Their ability to differentiate between "soft" and "hard" formations has proved equally valuable as a guide to determining the exact point of ingress of water to the hole and thus indicating the proper place for squeeze cementing or other methods of obtaining a water shut-off.

Correlation With Electrical Log

Whether a company is only embarking upon a program of recording drilling time studies or has been employing this type of analysis for some time, it is a good idea to check the results obtained by comparison with electrical or other methods of accurate logging. In fact, true advocates of drilling time studies go so far as to say that it is a good idea to use time studies to check on the accuracy of the other methods of logging.

Picked more or less at random, the accompanying chart depicts the correlation between an electrical log and a drilling time study obtained on a well in the Magnolia field, Arkansas. Although both the electrical log and the drilling time data were recorded in a greater portion of the well, only the section of greatest interest is presented.

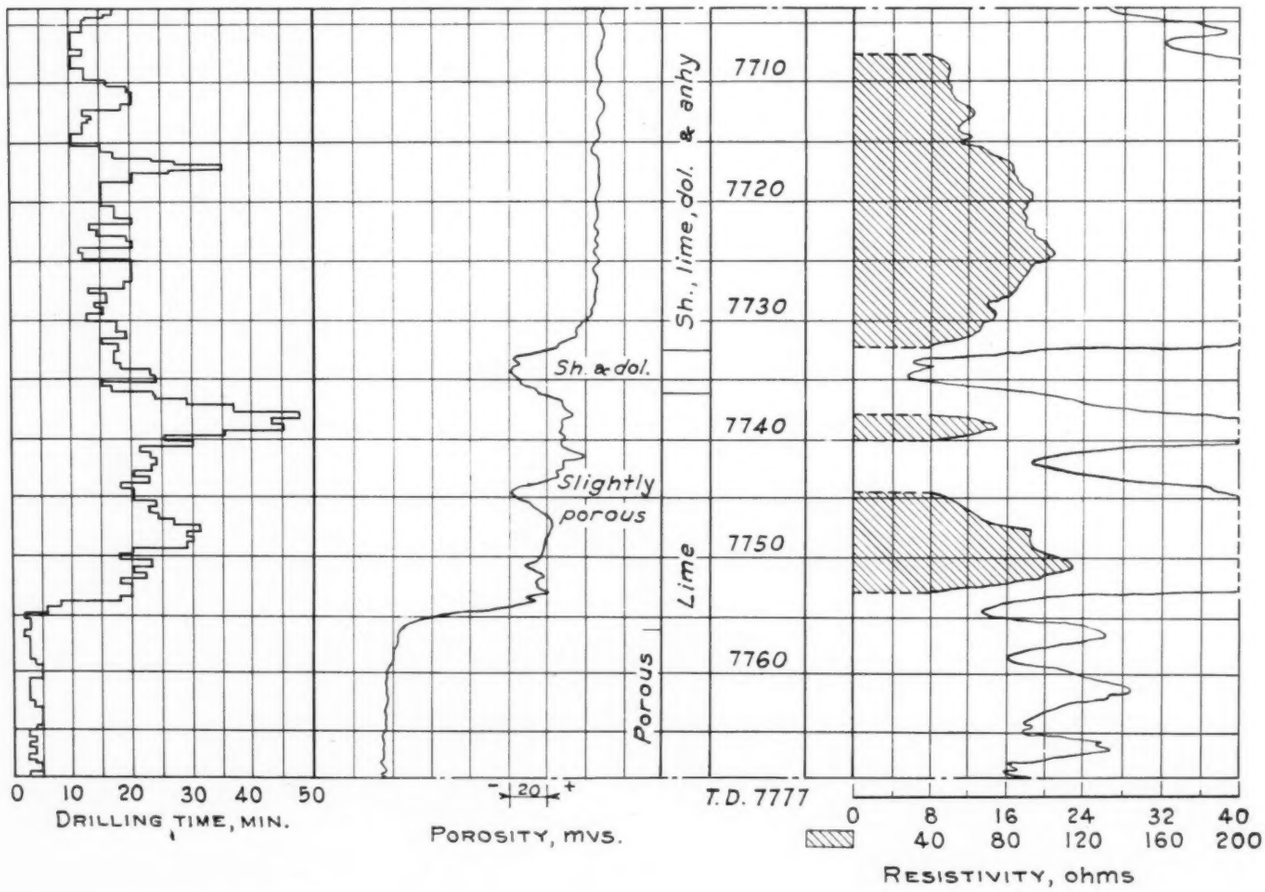
The point of greatest interest is, of course, at a depth of approximately 7755 ft., at which the drilling time drops abruptly from about 20 min. per ft. to 3-5 min. per ft., thus marking the top of the porous lime. The extreme variation in drilling time at this depth is well supported by the abrupt change in the self-potential curve of the electrical log pictured in the center of the chart and supported to some extent by the position of the resistivity curve on the right.

Other points of greatest interest occur at depths of approximately 7738 ft. and 7717 ft., where the drilling times increase to about 48 min. per ft. and 35 min. per ft., respectively. In both cases, this increase in drilling time is accompanied by a perceptible increase in the resistivity recorded by the electrical log, thus validating the accuracy and sensitivity of an accurate drilling time record.

Abrupt changes in drilling time such as these are not unusual in any well. As in an electrical log and in many other types of recorded data, the absolute values recorded are not of so much importance as the relative values observed.

Intensive study of drilling time has only recently become a more general practice. It may well be that when sufficient data have been gathered and enough study has been made of the results obtained, a more precise gauge of drilling procedure may be evolved that will add greatly to knowledge of the formations drilled and in some instances eliminate more costly methods of analyses.

Correlation between an electrical log and a drilling time study obtained on a well in the Magnolia field, Arkansas



The Technology of Refining Processes

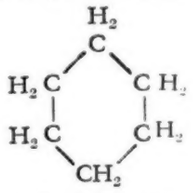
Article 7

Refining Methods for Lubricating Oils

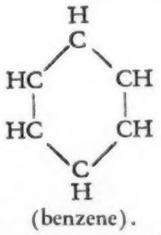
By
ARCH L. FOSTER
The Lubri-Zol Corporation, Cleveland, Ohio

SO MUCH has been learned of lubricating-oil refining, and yet so little is really known about the composition of lubricants and about the most efficient means for improving their basic qualities that any dissertation purporting to cover the subject, even briefly, must be undertaken with numerous qualifying limitations. In these articles we shall present merely the "highlights" of some of the fundamentals of lubricant refining, and refer the interested investigator to the voluminous literature of recent years for all but the broader details of lubricating oil processing. Because of space limitations we shall confine our attention chiefly to crankcase oils.

Recently the investigations of the U. S. Bureau of Standards have thrown considerable light on the chemical composition of lubricating fractions of petroleum (cf. Mair, Willingham and Streiff, *Proc. Am. Chem. Soc.*, Sept., 1938, and other publications by Bureau of Standards). These investigators find that, after wax and asphaltic materials are removed from a Mid-Continent lubricating fraction, about 70 percent of the remaining material consists of naphthenes of from one to three rings per molecule, with small amounts of four-ring naphthenes. The naphthene ring is typified by the following:

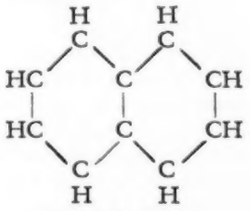


Twelve percent of the lubricating fraction is composed of one aromatic ring and one to three naphthenic rings per molecule, with some sulphur and oxygen compounds. The aromatic ring is typified by the benzene ring:



(benzene).

Benzene is a highly unsaturated and reactive complex, but not olefinic in constitution or properties. About 10 percent of the fraction is made up of one double-ring aromatic radical, the rings interconnected by two carbon atoms, combined with about two naphthenic rings, along with some sulphur and oxygen. This double-ring complex is represented by:



(naphthalene).

ARCH L. FOSTER

after receiving bachelor's and master's degrees in organic chemistry from the University of Texas, in 1922 became affiliated with the research and development division of the Gulf Refining Company, where he remained until 1925—From 1925 until 1929 he was with the Petroleum Division, U. S. Bureau of Mines, at San Francisco, California, in charge of the chemical research laboratory—During that period, 1927-29, he was assistant to the chief engineer, Petroleum Division, Washington, D.C.—From 1929-39 was technical editor of *The National Petroleum News*, Cleveland, Ohio—In 1939 joined the staff of The Lubri-Zol Corporation as sales engineer, having as his field of activity lubricants and lubricant-treating methods.

About 8 percent of the product is composed of more than two aromatic nuclei, similarly interconnected, together with one or two naphthenic rings per molecule, also associated with sulphur and oxygen and some nitrogen compounds. Obviously these proportions represent one fraction from one source, and doubtless the proportions of these main constituents vary more or less widely in oils from different sources. Note also that only one of these three groups includes no aromatic radicals. The naphthenic molecules are probably the least susceptible to reaction tendencies with outside elements such as oxygen; the double-ring aromatic radicals are more reactive and thus more susceptible to deterioration in the presence of heat and oxygen in service, and the benzene ring type is the most reactive of the list.

In general the more aromatic the molecule the more "polar" it is, that is, the greater affinity it will exhibit toward metal surfaces such as those of bearings and journals, and more tenaciously will it cling to these surfaces to resist being rubbed away. This propensity is due to orientation of the "polar" or reactive groups in the molecule adjacent to the metal surface, with the less reactive groups extending away from the surface, pendant-fashion. Also the more aromatic the molecule the more susceptible it is to chemical action by oxygen, and the less stable it is to heat decomposition. Paraffin or wax is objectionable in the finished lubricant chiefly because of effect on pumpability at low temperatures, and is therefore removed largely for that reason. It is not considered an impurity so far as lubrication goes, being in itself at best a fair lubricant, but undesirable from a practical viewpoint. Asphaltic materials must be removed as completely as practicable, inasmuch as they have no extenuating virtues to warrant their inclusion in the finished lubricant. Being very unstable under heat, their presence introduces numerous undesirable difficulties in the use of the product.

The primary method for refining lu-

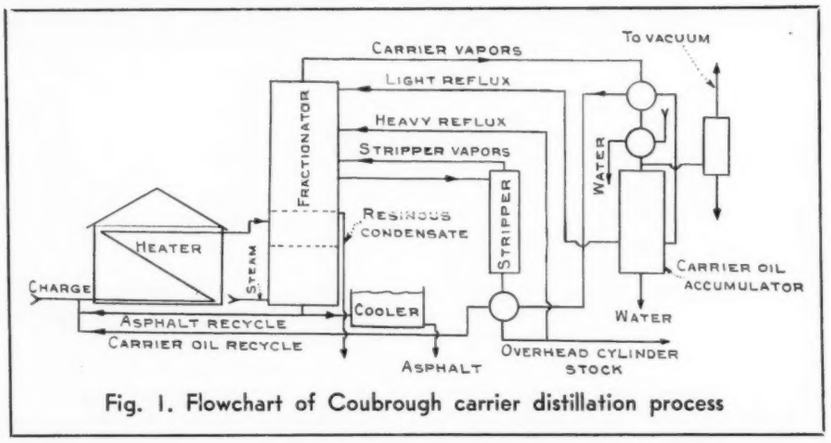


Fig. 1. Flowchart of Coubrough carrier distillation process

bricants is separation of constituents by boiling ranges, i.e., by distillation. The main consideration is good fractionation without decomposition; the major portion of a lubricant fraction will not vaporize at atmospheric pressures without partial or complete decomposition. Partial pressure of the petroleum hydrocarbons is reduced by the introduction of steam, and distillation is carried out at temperatures of 650-750°F., plus steam in volumes of 100 percent or more in the case of the heaviest fractions. Pressure on the fractions may also be reduced by maintaining a vacuum in the still-fractionator unit, by means of a barometric condenser, with auxiliary exhauster pumps to remove the uncondensable vapors from the system. Frequently steam is used in the vacuum unit also to aid in reducing further the partial pressure of the hydrocarbons to promote vaporization.

Other means of obtaining the partial pressure reduction so essential for distillation include the addition of vaporizable but separable liquids to the heavier lubricant fractions. A recently-developed process will be described here to illustrate the operation of vacuum stills when used with any type of "carrier" fluid, such as steam, light oils, etc. In the Coubrough process, there is added to the reduced crude fraction, varying quantities of kerosine or light gas or heating oil, which distills with the heavy materials and so reduces the partial pressure required to vaporize the latter. This is a distinct advantage over using steam in many cases, it is claimed, as kerosine may be condensed at about 300°F., using a 35-40°F. rise in condenser water temperature, even when the inlet temperature of the water is relatively high. Steam must be condensed under much lower temperatures, particularly if operated under vacuum. The molal heat contents of kerosine and of steam are about the same, that for steam being about 1100 B.t.u., and for kerosine about 100 B.t.u. per lb. Kerosine's molecular weight is ten or more times that of water; therefore, in molal weight terms the heats carried by the two are approximately equal.

The requirements for a "carrier" liquid for these purposes include low molecular weight compared to the fraction to be distilled; it must have an endpoint 50°F. or more below the initial boiling point of the material being distilled, and it must be completely condensable under the reduced pressures in vacuum distillation units. Obviously, as the carrier is recycled through the system, it must not contain materials that decompose nor products that will contaminate either the lubricating oil distillate or the carrier itself, under repeated recycling, vaporizing, and condensing, in the system.

A typical flow chart is shown in Fig. 1. The reduced crude or other charge stock is normally received from a previous distillation while yet hot, and is sent directly to the heater coils, mixing with the recycling carrier liquid on the way. Temperatures of the order mentioned above are attained in the coils, the mixed feed and carrier being flashed in the fractionator flash compartment, entering tangentially usually, to aid vaporization and reduce liquid entrainment. It is stated that the process can operate under the equivalent of 1 mm. absolute pressure because of the partial pressure effect of the carrier. Actual barometric pressure of 70 mm. or somewhat lower in the flash chamber is obtained. Proportions of ½ to 1½ parts of carrier to 1 part of charge may be used. Carrier vapors are taken from the top of the tower, carrier reflux is used, and intermediate reflux just above the draw-off for the lubricant fraction is also added to improve fractionation of the main product. Asphaltic bottoms are stripped with steam as is the lubricant fraction or fractions drawn from the side of of the tower. In the chart an intermediate resinous condensate is shown, removal of which further improves the properties of the cylinder stock distillate obtained. Elimination of these resins also permits better control of the penetration and other properties of the asphaltic bottoms produced.

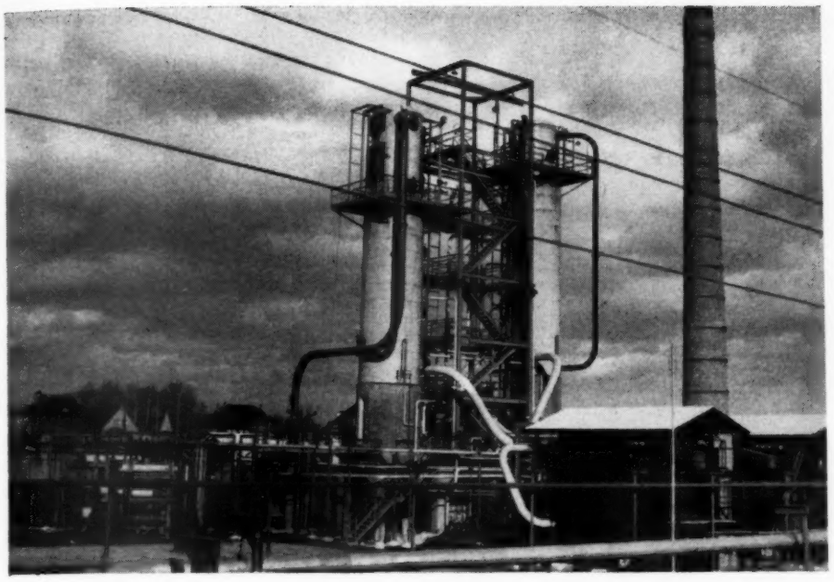
By this method (Kraft and Bloomer, *Proc. Western Pet. Ref. Ass'n*, 1938) a short residuum from Van Zandt crude of 12.1 A.P.I. gravity and 610°F. flash is reduced to 71 percent of 73 penetration asphalt and 29 percent of 550°F. flash heavy lubricating distillate, with a viscosity of 134 at 210°F., and a V.I. (viscosity index) of 76. This product can be further refined by acid treatment, solvent extraction, etc. An Oklahoma City crude residuum of 22.0 A.P.I. gravity and 152.5 viscosity at 210°F. was reduced to 93 percent heavy distillate and 7 percent of 142 penetration asphalt, the lubricant fraction having a flash of 505°F. and a viscosity of 104 at 210°F.

Because of the use of a carrier liquid of high condensing temperature, which at the same time differs in boiling range from that of the heavy residue so widely that the two can be completely separated by fractionation under vacuum, this process is said to offer definite advantages in operating costs where the amount of cooling water is limited, such as in western localities.

Other methods are employed for distilling heavy oils, such as the use of mercury vapor and of diphenyl as heat transfer media. These methods have not been applied widely but appear to have shown advantages in certain instances, particularly in the mercury vapor process. This method passes preheated oil in a thin film over a metallic baffle or surface that is heated on the opposite side by mercury vaporized in a special "boiler." Better vaporization of the oil is claimed, with less overheating and incipient cracking of the oil.

Chemical and Physical Refining Methods—Acid Treating

The oldest chemical treatment for lubricating oils elsewhere than in Pennsylvania is sulphuric acid. This acid removes asphaltic, resinous, sulphur, oxygen, and nitrogen compounds, and in varying degree some of the more aromatic and reactive hydrocarbons, partly by direct solution in the concentrated acid (98, to 105 percent or "fuming" acid) and partly by chemical reactions that form sulphonates, sulphate esters and acid esters together with products even more complex. Some of the acid from the sludge so formed may be recovered by hydrolysis



(Photo Courtesy The Lummus Company)

Coubrough vacuum distillation unit, processing 70 percent reduced crude to 18 percent bottoms, producing penetration asphalt, and overhead lubricating stock. Conventional vacuum distillation is able to reduce this charge stock to only 25 percent bottoms

and concentration methods, showing that it either does not combine entirely with the petroleum materials or that these compounds are loosely held and may be hydrolyzed with water.

Filtration

Filtration through adsorbent natural or synthetic earths has been and still is one of the most efficient methods for eliminating lubricant impurities and improving certain characteristics of the oil. These properties are, especially, color—not important in itself—demulsibility, and carbon residue. Filter media used include Fuller's earth, an alumina-silicate, that is, a naturally occurring mineral; bauxite, also composed chiefly of alumina and silica; filtrol, a synthetic product, and porocel, a semi-synthetic material.

Fuller's earth is the product longest used by the refining industry; bonechar, a product obtained by carbonizing bones to form a type of "activated carbon," was used in earlier days especially in Pennsylvania but is used now only for special purposes if at all. Fuller's earth is reduced to small particle size for percolation filtering, and to finely granulated condition for contact methods. Being a product in which the particles are filled with myriads of microscopic pores, it possesses also the property of adsorbing on the greatly increased surface of these pores the resinous, asphaltic, and color-bodies found in the raw oil. The raw product, after pulverizing, is graded into different sizes, ranging from, say, those that pass a 16-mesh screen and are held on a 20-mesh, to fine dust that may pass a 200-mesh screen, 30-60 mesh or 60-100 mesh being the sizes most commonly used for lubricating oil treatment. The material is then heated in a revolving furnace that slopes downward, the "clay" entering at the higher end and tumbling downward along the rotary, cylindrical "kiln" to which a slow rotational motion is imparted by an outside-driven gear system. Heat is applied by flame or hot combustion gases that enter the lower end and pass upward counter-currently to the downward-moving clay, drying and heating it to a predetermined temperature to activate it for use. The hot, dry clay dumped from the kiln is stored and kept as dry as possible until used.

Other and more modern, probably much more efficient kilns used for this purpose are now widely employed for clay "burning," such as the Nichols-Herreshof furnace, in which parallel floors are placed in a large vertical cylinder. Hot combustion gases enter the bottom of this cylinder and pass upward alternately from center to circumference and from circumference to center, passing over and heating the clay on the floor surfaces. The clay enters the top of the cylinder and is gradually pushed by revolving "rabbles" from the outside edge to the center where it drops through an annular opening onto the level below, on which the rabbles are set to move it outward to the circumference of that level. Temperatures are so controlled that the clay is properly dried and activated by the time it reaches the lowest level, from which it is dumped and stored for use. Ten, twelve, or more floors or levels may be included in this furnace; the continuous mixing and tumbling of the clay as it is forced over the heating levels insures uniformity of heating and of the final condition of the material.

In contact filtration the finely divided "dust" clay is stirred intimately into the oil to be clarified and the slurry is pumped through fine-mesh filter presses to remove the clay. In percolation filtration the coarser grades of clay are dumped into cylinders, usually vertical, which will contain 30 tons or more—10 to 20 tons being more usual—and the oil is pumped through this porous mass. In either type of operation the viscosity of the oil may be reduced by heating to some temperature such as 150-200°F., at the choice of the refiner, as in the case of low viscosity neutrals, or may be "cut" with light naphtha of narrow boiling range in the case of heavy residual stocks, to facilitate flow rates and reduce pumping pressures and costs.

In practice, enough clay is added to a given raw product in contact filtration to reduce color to a predetermined value. In percolation operations, the first oil through the filter when starting a run is practically water-white, the color gradually becoming darker as the clay loses its efficiency by adsorption of impurities. Finally the color is dark enough so that the blend of all the oil put through the filter during the run is that desired by the operator. Oil flow is stopped, the residual oil clinging to the clay is washed out with naphtha, the clay is steamed free of naphtha, dumped from the filter to go to the burners, and the filter recharged with fresh clay to continue the cycle.

The spent clay with its load of impurities is returned to the burner in which this organic material is burned away to reactivate the clay in the same manner as previously described for new clay. This cycle may continue indefinitely, the number of times it may be reactivated being dependent on the physical strength and the amount of "fines" produced by the operations; on the loss of clay per cycle, which gradually reduces the amount of material that may be returned to the cycle after each filtration and burning, and on the relative efficiency of the clay as a filter medium after each reburn-

ing. In general these details of use and revivification apply equally to the use of other materials discussed below.

Bauxite, a natural mineral predominantly alumina but containing smaller amounts of silica, iron oxide, etc., is also widely used both for light and heavy distillates. It is mined, calcined, activated, and sized for use in much the same manner as is Fuller's earth. If carefully selected material is used, the "dust-loss per burn" is reported to be from 0.5 to 2.0 percent. Bauxite is almost twice as heavy as Fuller's earth, but its filtering efficiency is only about 70 percent that of the earth. It offers an advantage in amount of filtration accomplished per filter unit, therefore, as a greater weight of bauxite may be used in a filter cylinder of a given size, even though efficiency is less by weight.

Repeated reburnings reduce the efficiency of bauxite to 80-90 percent of its original efficiency *(Nat. Pet. News,* April 20, 1938, page R-195). It therefore can be used economically so long as it lasts, 50 reburnings being theoretically possible with a 2 percent dust-loss each time. With lower dust-loss rates the efficiency of the material after 50 reburnings is equal to that of Fuller's earth after 17 reburnings, it is stated.

Bauxite is reactivated at higher temperatures than Fuller's earth, burning temperatures of 1200-1300°F. being used, especially when filtering heavy stocks. Bauxite exerts a "solvent" action or effect on finished oil qualities when new, but this effect is lost after repeated revivifications (Hubbell and Ferguson, *Proc. A.P.I.,* Nov., 1938). It may be used to advantage during the first several reburnings as a filter medium for light distillates, and later employed on residual stocks of the bright-stock type. Plant experience shows that in reburning bauxite 28 times, its efficiency may be reduced to 87 percent the efficiency of new bauxite when filtering to 7½ color; when reducing stocks to a 5-color the efficiency may drop as low as 55 percent under certain conditions. An average efficiency of used bauxite on naphtha-diluted heavy stocks is rated as 90 percent by these investigators. They show dust-losses of about 1.5 percent per burn, or 60 to 70 cycles with a high overall efficiency; a fact that reduces considerably the overall cost of bauxite per unit of oil refined. The solvent action referred to above, which is very high in the new bauxite, gradually is reduced by reburning until it is "no higher than that of other commercial adsorbents." The effect of this solvent action is shown by filtering Pennsylvania cylinder stock through new bauxite to 7½ color, which gives a gravity of 27.6 A.P.I., carbon residue of 0.75, and undewaxed viscosity of 132 seconds at 210°F. The same stock filtered to the same color through the same type material after it had reached its 25th burn gave 27.1 A.P.I. gravity, carbon residue of 1.35, and viscosity of 136 at 210°F.

Bauxite as a filter medium has a strong effect on oil "bloom," a property of the oil of little practical significance so far as lubricating value is concerned, but which often is an important sales point. As the bauxite is reburned and its solvent action decreases, the cast of the finished oil improves until it equals that imparted by new Fuller's earth. This rate of improvement in the used bauxite may be hastened by underwashing and/or by increasing the temperature of burning.

Typical data on the effect of bauxite as a filter medium show that the carbon residue of oils so filtered may be reduced to a much lower value than with Fuller's earth of comparable grade. A Pennsylvania stock filtered through new bauxite showed a carbon residue of 1.38; through reburned bauxite, 1.69; the same stock through new and reburned Fuller's earth had carbon residues of 1.90 and 1.98, respectively. *(Nat. Pet. News,* loc. cit.). Viscosity of the stock through new bauxite at 100°F. was 2860, through reburned bauxite 3034. The same viscosities from Fuller's earth were 3184 and 3286, respectively. Colors of filtered oils were identical in every case.

Yields from bauxite and from Fuller's earth per single filtration are somewhat greater with the former when obtaining the same color. For 8 color (A.S.T.M.) in each case, using 275 cu. ft. (8.5 tons) of bauxite, and the same volume (5 tons) of earth, the bauxite yield was 71 percent greater (45 bbl. as compared to 26.5 bbl.) than from the earth, with equal *volumes* of each, but 70 percent greater *weight* of bauxite. Yields on a weight basis in this case were practically equal. The bauxite filtration required 41 hr. as compared to 24 hr. with the earth. Total time for the filtration-cleanout-blowing-washing-steaming-dumping cycle was 104 hr. with bauxite, 87 hr. with earth, all steps except percolation requiring the same time. The time efficiency of the bauxite was, therefore, 19.5 percent less than the earth. Net filter capacity advantage can therefore be calculated as nearly 42 percent greater for bauxite, in this instance, in which earth and bauxite had equal weight efficiency at the beginning of the runs.

Refinery operations and the conditions to be met vary so extremely in different plants that space is not available to give a comprehensive tabulation of results of filtration under a wide variety of conditions. Bauxite and some other products give better results that do Fuller's earth when filtering at higher temperatures of 250-300°F., at which filter rates are accelerated because of lower viscosities of the oils. Bauxite-filtered products, at such temperatures, do not exhibit the cracked odors in the finished oil evidenced in earth-filtered oils. Oil cast from the bauxite filtration is improved by these higher temperatures, which gives two points of advantage for the refiner in using these methods.

Filtrol is a synthetic "clay" of very high efficiency especially in contact filtration, the use of which has been retarded somewhat by its high initial cost. A typical operation is to mix the clay with reduced crude and pass the slurry through the furnace coils using an abrasion-resistant type pump. The lighter overhead products are flashed in a fractionator, the heavy residuum-clay slurry being withdrawn from the tower bottom after stripping, and is pumped direct to a Sweetlands or other type of leaf filter where the adsorbed clay and the impurities are removed from the hot oil. Filter temperatures of 500°F. or thereabouts have been used, avoiding the necessity for diluting the heavy stock to reduce viscosity. The clay may be reactivated in a manner generally similar to that previously described.

Porocel is a less expensive product also showing a high filter efficiency, which is used similarly to other clays. Its use in refining lubricants is increasing in many parts of the country.

One of the new developments is that of preparing Fuller's earth and other clays in artificial form by, for example, extrusion methods. The pulverized clay is forced in the form of a plastic mass through openings in a heavy plate, extruding the product in the form of short cylinders, blocks, etc., in such dimensions that may be most efficient for the purpose in mind. Good improvement in efficiency, in handling, in reactivation, and in other ways are claimed for these new type products; less attrition of the medium, less dust-loss, and less expensive handling are some of the mechanical advantages found for these special forms of filter media.

EDITOR'S NOTE: The eighth article in this series will continue the discussion of lubricant manufacture, and will present methods for dewaxing and extraction of heavy distillate and residual oils.

Exterior view of Flora station. Two 10-in. pumping units are installed outside the building and six 12-in. units inside

A PETROLEUM ENGINEER EXCLUSIVE FEATURE

By

FRANK H. LOVE

Managing Editor

Construction Features of New Illinois Pipe Line

Pumping equipment of a type designed to cope with possible changing conditions and varying capacities

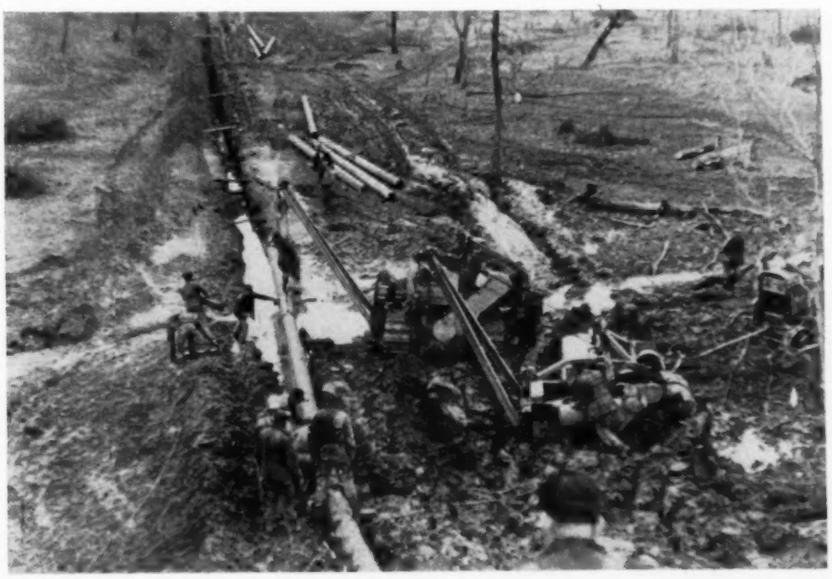
CONSTRUCTION work by the Sohio Pipe Line Company, involving the laying of a total of 311.7 miles of 10-in. and 12-in. line, has added materially to the outlet facilities for crude oil produced in the Illinois Basin area. Recent construction has consisted of two principal projects, the building of a 10-in. line from Salem to Stoy, Illinois, a distance of 71.7 miles, and a 12-in. line from Stoy to Lima, Ohio, a distance of 240 miles. The latter line is the more recently completed. This new line parallels as far as Hagerstown, Indiana, an existing 6-in. that was acquired last summer from the Tide Water Pipe Line Company, Inc., and from that point extends in a direct line southeastward to Lima, Ohio.

The existence of the 6-in. line was a tangible aid in the construction of the new line in several respects. For example, experience with the older line indicated where corrosive soil was to be found. From this information, as well as from soil surveys, it was determined in what areas the pipe should be coated. Incidentally, it was deemed essential to coat only 20 miles of a total of 240 miles of line. Another instance in which the 6-in. system was useful, was with respect to the construction of station buildings. To house pumping equipment on the new system metal additions were provided to the existing brick structures. This effected a considerable economy in installation cost.

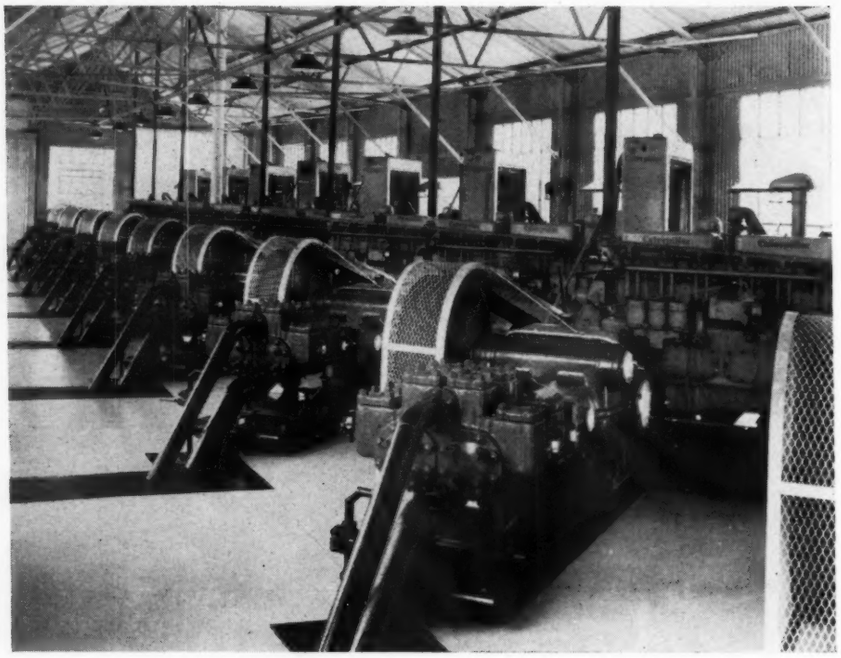
Principal difficulties encountered in performance of the work were the result of spring thaws, during which period a considerable part of the line was laid, and on a stretch of 12 miles the terrain was exceptionally hilly. Conditions under which some of the work had to be done is shown in several of the accompanying illustrations. At times the trucks upon which the electric welding machines were mounted mired-down to their hubs or deeper and on occasion had to be assisted by tractors.

The general nature of the terrain traversed was rolling and hilly country. Two rivers, the Wabash and White, and two creeks, the Eel and Blue, were crossed. The customary river clamps were installed on the wider crossings. The narrow creeks were ditched, but the pipe was allowed to rest on the bottom of the rivers, weighted by clamps.

Three pumping stations were pro-



At times mud, such as shown here, made difficult the laying of the line



Interior of Weems station, which has 15 pumping units, 9 inside the building and 6 outside

vided on this section of the line: at Stoy, Illinois, Brooklyn, Indiana, and Hagerstown, Indiana. All are equipped with multi-cylinder Diesel engines driving centrifugal pumps through speed increasers. At Stoy, three 400-hp. engines were installed; at Brooklyn, the same number and size units, and at Hagerstown there are two 450-hp. engines.

Truman Smith Construction Company and Sheehan Pipe Line Construction Company were the contractors for this 240 miles of 12-in. line.

Salem-Stoy Line

Previously to the construction of the above-discussed system, a 10-in. line was laid from the center of the Salem, or Lake Centralia field to Stoy, laterals branching off to the Clay City and Noble fields at points between Flora and Olney.

No construction difficulties were encountered and conventional pipe-line methods were employed throughout. Seamless steel pipe was delivered by rail to construction sites and strung from those points by trucks. Joints were electric welded and the entire line was coated and wrapped. The nature of the terrain through which the line passed was flat and rolling and no creeks or rivers of any consequential width or depth had to be crossed. Williams Brothers Corporation contracted the line.

Pumping equipment installed is of a type designed to cope with changing conditions that might require pumping of varying capacities. The units are of the small high-speed Diesel type convertible to gas, driving plunger pumps through V-belts. This type unit can easily be dismantled and moved to a new location in event of capacity decline; and it has the further feature of lending itself to almost 100 percent salvage.

The Weems station is situated in the center of the Salem field. Original plans were for this station to pump 40,000 bbl. of crude oil per day, later this was increased to 50,000 bbl., and then to 60,000 bbl., which is the present capacity. To attain this capacity there are 15 pumping units, two being standbys. Each unit consists of a 2½ to 5 by 10 horizontal duplex piston power pump driven through a V-belt by a converted gas engine. The engines have water-cooled manifolds and large radiators. The units, of which there are nine inside the station building and six outside, are mounted on 8-in. H-beam skids. When pumping at capacity this station operates at a pressure of 900 lb.

To pump the present volume of 60,000 bbl. per day all 15 units are utilized, two functioning as standbys. Should, however, the volume decline to 50,000 bbl. per day, use of only 12 units will be necessary, one of these being used as a standby, and in event of a decline in the pumping volume to 40,000 bbl. per day, but 9 units will be needed, one operating as a standby.

At the Flora and Olney stations, pumping installations are identical except that the pump liners and pistons are of different size to conform with a difference in capacity and pressure. Each station is provided with six 12-in. and two 10-in. pumps. A 12-in. pumping unit consists of 4 to 7 by 12 horizontal duplex power pump driven through a V-belt by a Diesel engine equipped to burn crude oil. The engine has a large-capacity radiator and water-cooled manifold. The 10-in. unit consists of a 2½ to 5 by 10 horizontal duplex power pump also driven by a Diesel engine. Both the 12-in. and the 10-in. units are mounted on 8-in. H-beam skids. The six 12-in. units are inside the station, whereas the two 10-in. are outside.

The Flora station, two miles north of Flora, Illinois, has a capacity of 60,000 bbl. per day at an operating pressure of 825 lb. per sq. in. Olney station, four miles north of Olney, Illinois, has a capacity of 64,000 bbl. per day at 750-lb. pressure.

Electric welding a joint of pipe

Vapor-Liquid Phase Equilibria in Hydrocarbon Systems

Part VII

Calculating the minimum number of equilibrium plates in fractionating columns

By

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and

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graduated with a bachelor's degree in chemical engineering from New York University in 1917—Served with the Aluminum Company of America at Massena, New York, with the Chemical Warfare Service at Washington, D C., then as production manager for the Union Special Machine Company in Chicago, and Youngstown Sheet and Tube Company at Evanston, Illinois—In 1920 joined the staff of the Department of Chemical Engineering, University of Michigan—Post-graduate studies led to the doctor's degree received in 1924—The professional degree of chemical engineer was granted by New York University in 1925.

DYSART E. HOLCOMB

received B.S. degree in chemical engineering from Texas Technological College in June, 1937, and M.S. degree in chemical engineering from the University of Michigan in June, 1938—During summer following completion of M.S. degree worked with technical service division, Humble Oil and Refining Company, Baytown, Texas—For two years and a half he was assistant in the chemical engineering department, University of Michigan, resigning recently to continue work for his Ph.D. degree in chemical engineering—He also is working with Dr. Brown on high-pressure equilibrium data and computations.

AS is well known,[1, 2] when operating a fractionating column on a two component, or binary mixture under such conditions that no overhead distillate is removed but all the vapors rising from the top of the column are condensed and returned as reflux, the separation of a given feed material into an overhead distillate product and a bottom residual product of specified composition can be accomplished with a minimum number of equilibrium plates in the column. The heat consumption and cooling water required are, of course, infinite for any amount of product obtained under such conditions, as no distillate or bottom product are removed from the column. Such an operation, however, although impractical, indicates the minimum number of plates that must be used in order to accomplish the desired separation and is, therefore, one of the limiting conditions of operation that should be determined if a complete study is to be made of a specific fractionating problem.

Correspondingly, the other limitation to the operating range is represented by a fractionating column of an infinite number of plates in which the minimum quantities of heat in the reboiler, and cooling water for the condenser, are required to give a unit quantity of distillate or bottoms of a specified composition from a given feed. This limiting condition will be considered later. Our interest at present is with the minimum number of equilibrium plates.

In a column operating under conditions of total reflux in which there is no distillate removed from the top of the column, a material balance around the top of the column and below any plate clearly indicates that the quantity of vapor rising from any plate is exactly equal to the quantity of liquid flowing on to that plate from the plate above. Using the symbol, V, to represent the number of moles of vapor rising from a plate, and the symbol, L, to represent the number of moles of liquid overflowing from a plate to the plate below for the total reflux:

$$V_{n+1} = L_n \quad . \quad . \quad . \quad (36)$$

where n represents the number of the plate in the column counting down from the top with the top plate numbered one.

Not only is the quantity of vapor rising from a plate equal to the quantity of liquid overflowing on to that plate, but also the composition of the vapor is equal to the composition of the liquid. Therefore:

$$y_{n+1} = x_n \quad . \quad . \quad . \quad . \quad (37)$$

where y is the mole fraction of any component in the vapor rising from a

[1]Badger and McCabe "Elements of Chemical Engineering," 2nd Edition, McGraw-Hill Book Company, Inc., 1936, p. 357-360.

[2]Walker, Lewis, McAdams, and Gilliland "Principles of Chemical Engineering," 3rd Edition, McGraw-Hill Book Company, Inc., 1937, p. 564-566.

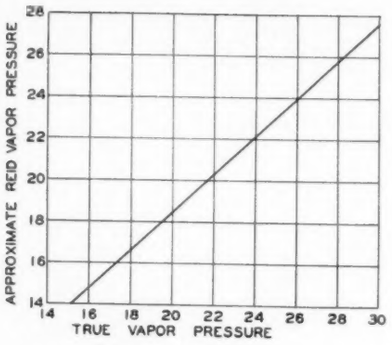

Fig. 15. Correction of Reid to true vapor pressure

plate and x is the mole fraction of that same component in the liquid.

It is a simple matter, therefore, to compute the composition of the liquid on each succeeding lower plate starting with the top plate of the column if the composition of the vapors at the top is known completely and accurately.

Unfortunately it is not possible to know the composition of the overhead product completely and accurately in the usual complex mixture, as the break-up of the feed into the distillate and the bottoms must be made for practical reasons on the assumption that the overhead distillate is free of the high boiling materials desired in the bottoms, and that the bottom product from the column is free of the low boiling materials desired in the overhead distillate. The method of computation is the same either for a limited number of plates down from the top of the column, or for a limited number of plates up from the bottom of the column. The procedure will be illustrated in the following example.

Taking a raw gasoline feed of approximately the same composition as given in Table 6*, it is desired to produce from this raw gasoline a finished or stabilized gasoline having a Reid vapor pressure of about 26 lb. at 100°F. It is desired to include in the bottom product of the column, or the finished gasoline, (1) substantially all pentanes and higher boiling materials, (2) all the normal butane except approximately 2 percent, which is allowed in the distillate to meet a specified tolerance requiring that 97.5 percent of the normal butane be recovered in the finished gasoline, and (3) the additional quantity of *iso*butane permitted under the vapor pressure specification.

The Reid vapor pressure is always less than the actual or true vapor pressure of the liquid gasoline as indicated in Fig. 15. This curve indicates that the true vapor pressure of the 26-lb. (Reid) finished gasoline should be 28.4 lb. at 100°F.

The composition of the finished or stabilized gasoline is then computed as follows: The composition of the finished gasoline is known except for its *iso*butane content so it is possible to compute the vapor pressure at 100°F. of the normal butane-plus fraction of the gasoline and add to this the partial vapor pressure of the *iso*butane at 100°F. in order to obtain the desired true vapor pressure.

The vapor pressures of the various hydrocarbons at 100°F. may be determined from either a vapor pressure chart or from Figs. 13a to 13h by reading the pressure at which $K = 1$ at 100°F., inasmuch as $K = 1$ for any component at its vapor pressure. It was necessary to determine the vapor pressure of the $C_6H_{14}+$ fraction from a vapor pressure chart as Figs. 13g and h do not go to a low enough pressure at 100°F. The vapor pressures of the other components were taken from Figs. 13a to 13f.

Let A = the moles of i-C_4H_{10} in the bottoms per mole of feed.

The moles of *n*butane in the bottoms will be (0.1935) (1.00-0.0207) = 0.1895.

Component	Moles in bottoms per mole of feed	Vapor pressure at 100°F. (lb. per sq. in abs.)
i-C_4H_{10}	A	75.8
n-C_4H_{10}	0.1895	51.8
i-C_5H_{12}	0.0732	20.6
n-C_5H_{12}	0.1208	15.4
$C_6H_{14}+$	0.1716	4.84
Total	0.5551+A	

The true vapor pressure of 26 lb. Reid vapor pressure gasoline is 28.4 lb. per sq. in. abs. from Fig. 15 so the sum of the partial pressures must equal 28.4 lb.

$$\frac{(A)(75.8)+(0.1895)(51.8)+(0.0732)(20.6)+(0.1208)(15.4)+(0.1716)(4.84)}{(0.5551+A)}=28.4$$

$47.4A = 1.75$

$A = 0.0369$ moles i-C_4H_{10} in bottoms per mole feed

$$\frac{0.0369}{0.5551+0.0369} = 0.0623 \text{ mole fraction of i-}C_4H_{10} \text{ in the bottoms.}$$

In this way the composition of the bottom product is determined as given in Table 9. The total moles in the finished gasoline per mole of feed is given in the fourth column. By subtracting the moles in the bottoms from the moles in the feed, the total moles of each component in the overhead distillate is given in column 6. The composition or mole fraction in the overhead distillate is given in column 5.

In this way the material balance for the column can be set up assuming that the high boiling materials desired in the bottoms product are absent from the top as has been described.

Computation of Minimum Number of Plates

As is outlined in the previous installment the minimum pressure for the operation of the column may be determined from the known temperature of the available cooling water. For a distillate having the approximate composition given in Table 9, the minimum pressure was computed to be 190 lb. per sq. in. absolute. Using an absolute pressure of 215 lb. per sq. in. corresponding approximately to a gauge pressure of 200 lb., a sufficient leeway is provided and the following computations will be made on that basis.

The first step is to compute the temperature of the vapors rising from the top plate. This was done by determining the dew point of these vapors as 109°F. in the manner described in the previous installment using the equilibrium constants for a pressure of 215 lb. per sq. in. as indicated in Table 10.

The composition of the liquid on the top plate is given in column 4 in Table 10.

TABLE 9

Composition of the raw gasoline feed, of the desired bottoms product (stabilized gasoline), and of the residual overhead or distillate

Component	Saturated liquid feed, mole fraction or moles	Bottoms		Overhead distillate gas	
		Mole fraction in bottoms	Moles of bottoms per mole of feed	Mole fraction in distillate gas	Moles of distillate gas per mole of feed
(1)	(2)	(3)	(4)	(5)	(6)
C_2H_6	0.0890			0.2180	0.0890
C_3H_8	0.2714			0.6650	0.2714
i-C_4H_{10}	0.0805	0.0623	0.0368	0.1073	0.0437
n-C_4H_{10}	0.1935	0.3201	0.1895	0.0097	0.0040
i-C_5H_{12}	0.0732	0.1236	0.0732	.....	.....
n-C_5H_{12}	0.1208	0.2040	0.1208	.....	.....
$C_6H_{14}+$	0.1716	0.2900	0.1716	.....	.....
Tota	1.0000	1.0000	0.5919	1.0000	0.4081

NOTE: The $C_6H_{14}+$ fraction has been assumed to have a molecular weight corresponding to that of normal heptane.

*Part V, May, 1940, issue.

TABLE 10

Component	y_1 Mole fraction in vapor	K at 215 lb. per sq. in. abs. and 109°F.	$x_1=y_1/k=y_2$ Mole fraction in liquid = mole fraction in vapor ÷K
CH_4	0.2180	3.08	0.0708
C_2H_6	0.6650	1.00	0.6650
i-C_5H_{10}	0.1073	0.458	0.2343
n-C_4H_{10}	0.0097	0.32	0.0303
Total	1.0000		1.0004

Using the composition of the liquid on the top plate as the composition of the vapor rising from the second plate (equation 37), the temperature and composition of the liquid on the second plate may be computed in a manner similar to that given in Table 11, column 4.

By repeating the above calculation for each successive plate composition obtained, plate-to-plate calculations may be made down the column for nine plates as shown in Table 11.

The sum of the mole fractions is not exactly unity in Table 11. Obtaining unity is not essential so long as these sums average within ± 1 percent of unity.

The temperature and composition of the vapors rising from the reboiler at the bottom of the column may be determined by calculating the bubble point of the liquid in the reboiler, B, the composition of which is the same as that given in column 3, Table 11, computed in the manner described in the previous installment using the equilibrium constants for a pressure of 215 lb. per sq. in. abs. as indicated in column 4, Table 12. Using the composition of the vapor rising from the reboiler as the composition of the liquid on the bottom plate, the temperature and composition of the vapor rising from the bottom plate may be determined by calculating the bubble point of this liquid at 215 lb. per sq. in. abs. as shown in Table 12, column 6. In this manner the plate-to-plate calculations may be made from the bottom of the column upward. The results of such calculations for seven plates above the reboiler are given in Table 12.

By comparing the composition of the liquid on the ninth plate as computed by working downward from the top of the column and the seventh plate as computed by working upward from the bottom of the column it can be seen that these compositions are approximately the same. The composition obtained by working downward from the top of the column, however, does not contain any pentane or hexane nor does the liquid composition obtained by working upward from the bottom of the column contain any propane or ethane. It is necessary, therefore, to go back up several plates above the ninth plate as computed by working downward from the top of the column and add a small amount of *iso*- and normal-pentane and repeat the plate-to-plate calculations down to the feed plate until the concentration of the pentane approximately matches that concentration as obtained by working upward from the bottom of the column. In a similar manner it is necessary to drop back several plates below the feed plate and add a small amount of propane and repeat the plate-to-plate calculations up to the feed plate until the propane approximately matches the concentration of the propane on the feed plate as obtained by working down from the top of the column. These adjustments for the heavier components above the feed plate and the lighter components below the feed plate are by trial and error and it may be necessary to make several assumptions as to the amount of pentanes that is added on some plate above the feed plate and the amount of propane that is added on some plate below the feed plate.

In adjusting for the pentane above the feed plate, the concentration of *iso*pentane on the sixth plate from the top of the column was assumed to be 0.00026 and the concentration of the normal pentane was assumed to be 0.000048 as shown in column 2, Table 13.

Using the composition of the liquid

TABLE 11

Stepwise calculations for total reflux (minimum plates) from plates 1 to 9

Component	$x_1=y_2$ mole fraction in vapor from second plate = mole fraction in liquid from top plate	K at 133 °F. and 215 lb., Fig. 13	$x_2=y_3$ mole fraction in liquid on second plate or vapor from third plate	K at 150 °F.	$x_3=y_4$ mole fraction in liquid on third plate	K at 165 °F.	$x_4=y_5$ mole fraction in liquid on fourth plate	K at 176 °F.	$x_5=y_6$ mole fraction in liquid on fifth plate	K at 183 °F.	$x_6=y_7$ mole fraction in liquid on sixth plate	K at 188 °F.	$x_7=y_8$ mole fraction in liquid on seventh plate	K at 192 °F.	$x_8=y_9$ mole fraction in liquid on eighth plate	K at 194 °F.	$x_9=y_{10}$ mole fraction in liquid on ninth plate
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
C_2H_6	0.0708	3.6	0.0196	4.0	0.0049	4.35	0.0011	4.6	0.0002	4.78	.....	....	.....	.....	.....	.....	.....
C_3H_8	0.6650	1.26	0.5275	1.45	0.3640	1.625	0.2240	1.76	0.1272	1.84	0.0691	1.91	0.0362	1.97	0.0184	2.0	0.0092
iC_4H_{10}	0.2343	0.615	0.3820	0.75	0.5080	0.86	0.5900	0.96	0.6150	1.01	0.6070	1.07	0.5680	1.095	0.5190	1.11	0.4660
nC_4H_{10}	0.0303	0.447	0.0677	0.55	0.1231	0.65	0.1894	0.735	0.2580	0.785	0.3285	0.83	0.3960	0.855	0.4630	0.88	0.5260
Total	1.0004		0.9968		1.0000		1.0045		1.0004		1.0046		1.0002		1.0004		1.0012

TABLE 12

Stepwise calculations for total reflux (minimum plates) from the bottom up and plate B-7

Component	x_B mole fraction in bottoms	K at 272°F. and 215 lb. Fig. 13	$y_B=x_{B-1}$ mole fraction in reboiler vapor = mole fraction in liquid on bottom plate (B—1)	K at 232°F.	x_{B-2} mole fraction in liquid on second plate	K at 215°F.	x_{B-3} mole fraction in liquid on third plate	K at 207°F.	x_{B-4} mole fraction in liquid on fourth plate	K at 202°F.	x_{B-5} mole fraction in liquid on fifth plate	K at 199°F.	x_{B-6} mole fraction in liquid on sixth plate	K at 197°F.	x_{B-7} mole fraction in liquid on seventh plate
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
iC_4H_{10}	0.0621	1.94	0.1205	1.5	0.1808	1.32	0.2385	1.25	0.2985	1.2	0.3585	1.175	0.4215	1.15	0.4850
nC_4H_{10}	0.3202	1.62	0.5195	1.21	0.6280	1.06	0.6650	0.99	0.6590	0.945	0.6230	0.915	0.5700	0.9	0.5130
iC_5H_{12}	0.1237	1.0	0.1237	0.69	0.0855	0.58	0.0496	0.535	0.0266	0.5	0.0133	0.49	0.0065	0.475	0.0031
nC_5H_{12}	0.2040	0.83	0.1693	0.565	0.0957	0.47	0.0450	0.425	0.0192	0.4	0.0077	0.386	0.0030	0.38	0.0011
C_6H_{14}+	0.2900	0.22	0.0638	0.123	0.0079	0.096	0.0008		.....		.....		.....		.....
Total	1.0000		0.9968		0.9979		0.9989		1.0033		1.0025		1.0010		1.0022

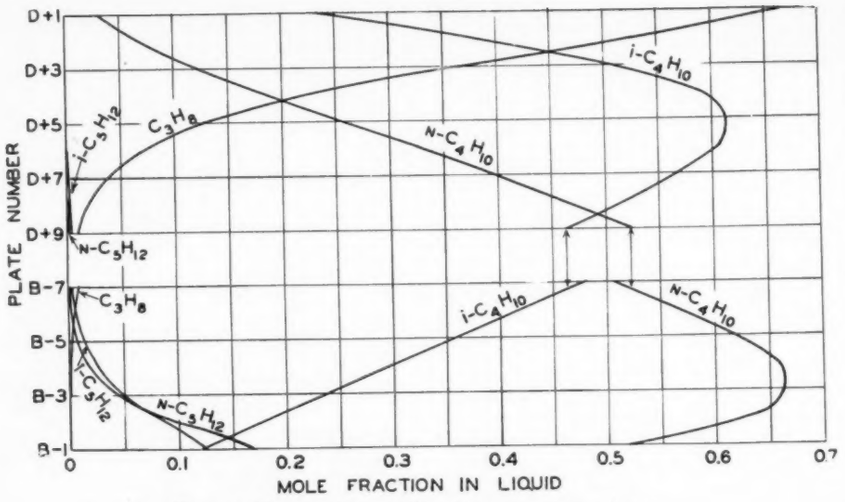

Fig. 16. Composition of liquids on various plates

on the sixth plate from the top as adjusted for the pentane, plate-to-plate calculations down to the ninth plate below the top were repeated as shown in Table 13, thus giving the concentration of *iso*pentane and normal-pentane on this plate as shown in Table 13, column 8. It is not necessary to adjust for the $C_6H_{14}+$ above the feed plate as the concentration of this component is so small that it may be neglected.

In adjusting for the propane below the feed plate, it was assumed that the composition of the propane on the third plate above the reboiler (B-3) was 0.00052 as shown in Table 14, column 2. Using this adjusted composition for the liquid on the third plate, the plate-to-plate calculations up the column were repeated as shown in Table 14, thus indicating the composition of propane on the seventh plate above the reboiler as given in Table 14, column 10. The concentration of ethane on and below the feed plate is small enough to be neglected.

By comparing the liquid composition as given in Table 14, column 10, and Table 13, column 8, it can be seen that these two compositions are approximately the same. The seventh plate above the reboiler, therefore, and the ninth plate below the top of the column are approximately the same plate.

If the compositions on each plate in the column are plotted against the plate number as shown in Fig. 16, it can be seen that the composition of the ninth plate (D + 9) from the top of the column is almost exactly the same as the composition of the liquid on the 6.7 (B-6.7) plate above the reboiler. As the ninth plate below the top and the 6.7 plate above the reboiler are the same, there are eight plates above plate (B-6.7) and the total number of minimum plates required for the separation given in Table 9 is 8 + 6.7 = 14.7 equilibrium plates in the column, or 16.7 equilibrium steps if the condenser and reboiler are each considered equivalent to one equilibrium plate in producing liquid distillate and bottoms.

TABLE 13
Corrected stepwise calculations for total reflux from plate 6 to plate 9 after introducing pentanes on plate 6

Component	$x_6=y_7$ mole fraction in liquid on sixth plate	K at 188°F.	$x_7=y_8$ mole fraction in liquid on seventh plate	K at 192°F.	$x_8=y_9$ mole fraction in liquid on eighth plate	K at 195°F.	$x_9=y_{10}$ mole fraction in liquid on ninth plate
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
C_3H_8	0.0691	1.91	0.0362	1.97	0.0184	2.0	0 0092
iC_4H_{10}	0.6070	1.07	0.5680	1.095	0.5190	1.12	0.4630
nC_4H_{10}	0.3252	0.83	0.3955	0.855	0.4625	0.885	0.5230
iC_5H_{12}	0.00026	0.425	0.00062	0.445	0.00138	0.46	0.0030
nC_5H_{12}	0.000048	0.34	0.00014	0.355	0.0004	0.37	0.0011
Total	1.0046		1.00046		1.00168		0.9993

If the compositions on each plate in the column are plotted against the plate number as shown in Fig. 16, it can be seen that the composition of the ninth plate (D + 9) from the top of the column is almost exactly the same as the composition of the liquid on the 6.7 (B-6.7) plate above the reboiler. As the ninth plate below the top and the 6.7 plate above the reboiler are the same, there are eight plates above plate (B-6.7) and the total number of minimum plates required for the separation given in Table 9 is 8 + 6.7 = 14.7 equilibrium plates in the column, or 16.7 equilibrium steps if the condenser and reboiler are each considered equivalent to one equilibrium plate in producing liquid distillate and bottoms.

The determination of the minimum number of plates for a given separation by the method described above may become somewhat time-consuming, especially when adjusting for the more volatile components below the feed plate and the less volatile components above the feed plate. It may be necessary to repeat these adjustments several times before effecting a match in composition. Another method that does not require these trial and error adjustments gives about the same result as the plate-to-plate calculations.

Equation 38, first derived by Underwood[3], will give about the same results for the minimum number of equilibrium plates as the plate-to-plate calculations provided it is applied correctly.

$$n+1=\frac{\log\left[\frac{x_{c,n+1}}{x_{d,n+1}}\times\frac{x_{d,o}}{x_{c,o}}\right]}{\log\left[\frac{K_{d\ (av.)}}{K_{c\ (av.)}}\right]} \quad (38)$$

where

n = number of plates between the plate from which the liquid is overflowing as denoted by the subscript, o, and the n + 1 plate as denoted by the subscript n + 1.

$K_{(av.)}$ = the arithmetic average value of K between the plate o and the plate n + 1.

c and d refer to the more volatile and the less volatile cut components, respectively.

When using equation 38, plate-to-plate calculations should be made downward from the top of the column and upward from the bottom of the column in the manner already indicated until the temperature gradient from plate to plate is substantially linear. Usually the temperature gradient from plate to plate is substantially

[3]Underwood, A. J. V. Transactions, Institution of Chem. Engrs., Vol. 10, p. 112-158, 1932.
NOTE: The derivation as given by Underwood is also given in the appendix of this article.

TABLE 14
Corrected stepwise calculations for total reflux from plate B-3 to plate B-7 after introducing propane on plate B-3

Component	x_{B-3} mole fraction in liquid on third plate above reboiler or plate B-3	K at 207°F.	x_{B-4} mole fraction in liquid	K at 201°F.	x_{B-5} mole fraction in liquid	K at 198°F.	x_{B-6} mole fraction in liquid	K at 197°F.	x_{B-7} mole fraction in liquid
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
C_3H_8	0.00052	2.18	0.00113	2.09	0.00236	2.04	0.00481	2.02	0.0097
iC_4H_{10}	0.2385	1.25	0.2985	1.195	0.3575	1.17	0.4180	1.15	0.4810
nC_4H_{10}	0.6650	0.99	0.6590	0.94	0.6195	0.91	0.5640	0.9	0.5070
iC_5H_{12}	0.0496	0.535	0.0266	0.495	0.0132	0.48	0.0063	0.475	0.0030
nC_5H_{12}	0.0450	0.425	0.0192	0.4	0.0077	0.385	0.0030	0.38	0.0011
$C_6H_{14}+$	0.0008		.....		.....		.....		.....
Total	0.9994		1.0044		1.0003		0.9961		1.0018

Please note typical 'Starcor' performance, as shown by these job-record cards—part of a success record on job after job that merits the Oil Man's consideration.

L 3901

FIELD: Horse Shoe Bayou State Land
TYPE OF JOB: Casing cement job
DEPTH OF WELL: Casing set at 11,631 ft.
MAX. TEMP.: 250° F.
SLURRY WEIGHT: 16 lb. per gal.
CEMENT USED: 'Starcor', 1500 sacks
MIXING TIME: 32 min.
PUMPING-DOWN TIME: 53 min.
MAX. PUMP. PRESSURE: 2300 lb.
REMARKS: X | Note ease with which 16-lb. 'Starcor' slurry was pumped into position. Well - 11,631 ft. deep. Temperature plenty hot — 250° F.

S 1417

FIELD: Lake Pelto, La.
TYPE OF JOB: Casing
DEPTH OF WELL: 5,500 ft.
MAX. TEMP.: 150° F.
SLURRY WEIGHT: 16 lb. per gal.
CEMENT USED: 'Starcor', 400 sacks
MIXING TIME: 18 min.
PUMPING-DOWN TIME: 27 min.
MAX. PUMP. PRESSURE: 1800 lb..
REMARKS: X | Formation in this field so soft that holes are almost always crooked. Another good 'Starcor' job, under very difficult conditions.

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linear below about the third or fourth plate from the top and above about the third or fourth plate above the reboiler. Care should be taken not to continue the plate-to-plate calculations for too many plates because the concentration of the less volatile components that do not appear in the distillate may become appreciable four or five plates below the top of the column, and the concentration of the more volatile components that do not appear in the bottoms may become appreciable three or four plates above the reboiler. Table 14 indicates the concentration of the propane on the third plate above the reboiler (B-3) is practically negligible, and Table 13 indicates the concentration of the pentanes and hexanes plus on any plate above the seventh is negligible. Equation 38 may therefore be applied between plates (B-3) and (D + 4) as follows, using values computed in Tables 11 and 12:

*iso*Butane $x_{c,n+1} = 0.2385$, (x_{B-3} from Table 12)

*n*Butane $x_{d,n+1} = 0.6650$

*iso*Butane $x_{c,o} = 0.5900$, (x_{D+4} from Table 11)

*n*Butane $x_{d,o} = 0.1894$

$$K_{d\,(av.)} = \frac{K_{d,o} + K_{d,n+1}}{2} = \frac{0.99 + 0.65}{2} = 0.82$$

$$K_{c\,(av.)} = \frac{K_{c,o} + K_{c,n+1}}{2} = \frac{1.25 + 0.86}{2} = 1.055$$

$$n + 1 = \frac{\log\left[\frac{0.2385}{0.6650} \times \frac{0.1894}{0.5900}\right]}{\log\left[\frac{0.82}{1.055}\right]}$$

or

$$\frac{0.2385}{0.6650} = \left[\frac{0.5900}{0.1894}\right]\left[\frac{0.82}{1.055}\right]^{n+1}$$

$0.359 = 3.12\ (0.777)^{n+1}$

$0.1151 = (0.777)^{n+1}$

$\log 0.1151 = (n+1) \log 0.777$

$9.17056—10 = (9.89042—10)\ (n+1)$

$— 0.82944 = — 0.10958\ n$

$n = 7.569$ (assume 7.6)

The value of n or 7.6 is the number of equilibrium plates between the fourth plate from the top of the column and the third plate above the reboiler. The total number of minimum plates in the column is, therefore, 7.5 + 4 + 3 or 14.6 equilibrium plates. If the reboiler and partial condenser are each considered to be equivalent to one equilibrium plate the total number of equilibrium steps in the column then becomes 16.6 as compared to 16.7 as obtained by the plate-to-plate calculations.

The results obtained by the use of equation 38 are for all practical purposes the same as the results obtained by the plate-to-plate calculations. It is recommended, therefore, that equation 38 be used as this method is much shorter than the method of plate-to-plate calculations and gives substantially the same results.

Equation 38 should be used only in that section of the column where the temperature gradient from plate to plate is substantially linear because the ratio of the average value of K for each of the cut components will not be constant unless the temperature gradient is substantially linear.

Appendix

Derivation of equation 38

From equation 37:

$$y_{a,n+1} = x_{a,n} \quad . \quad (37)$$

$$y_{b,n+1} = x_{b,n}$$

$$\frac{x_{a,n+1}}{y_{b,n+1}} = \frac{x_{a,n}}{y_{b,n}}$$

$y = Kx$

$$\frac{x_{a,n+1}}{x_{b,n+1}} = \frac{K_b x_{a,n}}{K_a x_{b,n}} \quad . \quad . \quad . \quad (37a)$$

Equation (37a) gives the variation in the ratio of any two components from plate to plate at total reflux.

If c and d are the two cut components, for plates 1, 2, 3, etc., the successive application of equation (37a) gives:

$$\frac{x_{c,2}}{x_{d,2}} = \frac{K_{d,2}}{K_{c,2}} \frac{x_{c,1}}{x_{d,1}}$$

$$\frac{x_{c,3}}{x_{d,3}} = \frac{K_{d,3}}{K_{c,3}} \frac{x_{c,2}}{x_{d,2}} = \left(\frac{K_d}{K_c}\right)^2 \frac{x_{c,1}}{x_{d,1}}$$

or for plate n + 1 below the plate o from which the liquid is flowing onto plate 1:

$$\left[\frac{x_{c,n+1}}{x_{d,n+1}}\right] = \left[\frac{c,o}{x_{d,o}}\right]\left[\frac{K_{d\,(av.)}}{K_{c\,(av.)}}\right]^{n+2}$$

$$\text{or } n + 1 = \frac{\log\left[\frac{x_{c,n+1}}{x_{d,n+1}} \times \frac{d,o}{x_{c,o}}\right]}{\log\left[\frac{K_{d\,(av.)}}{K_{c\,(av.)}}\right]} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (38)$$

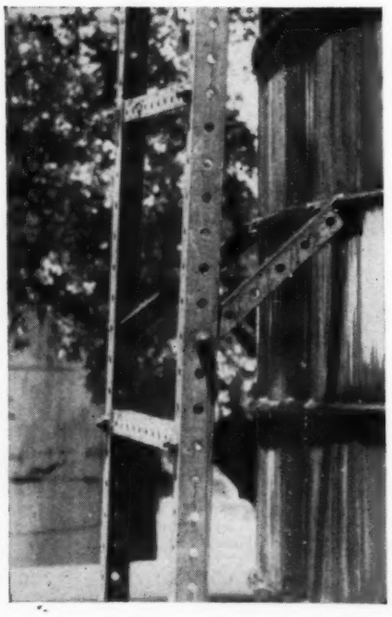
P 643.

Flexible Attachment for Tank Ladder

By CHAS. C. LYNDE

AS wooden tanks shift under varying conditions of load, and staves swell or shrink depending upon exposure, the usual method of attaching ladder brackets to the stave with lag screws or bolts imposes an unnecessary strain on the wood at this point, resulting in eventual pulling out of the screws or damage to the ladder.

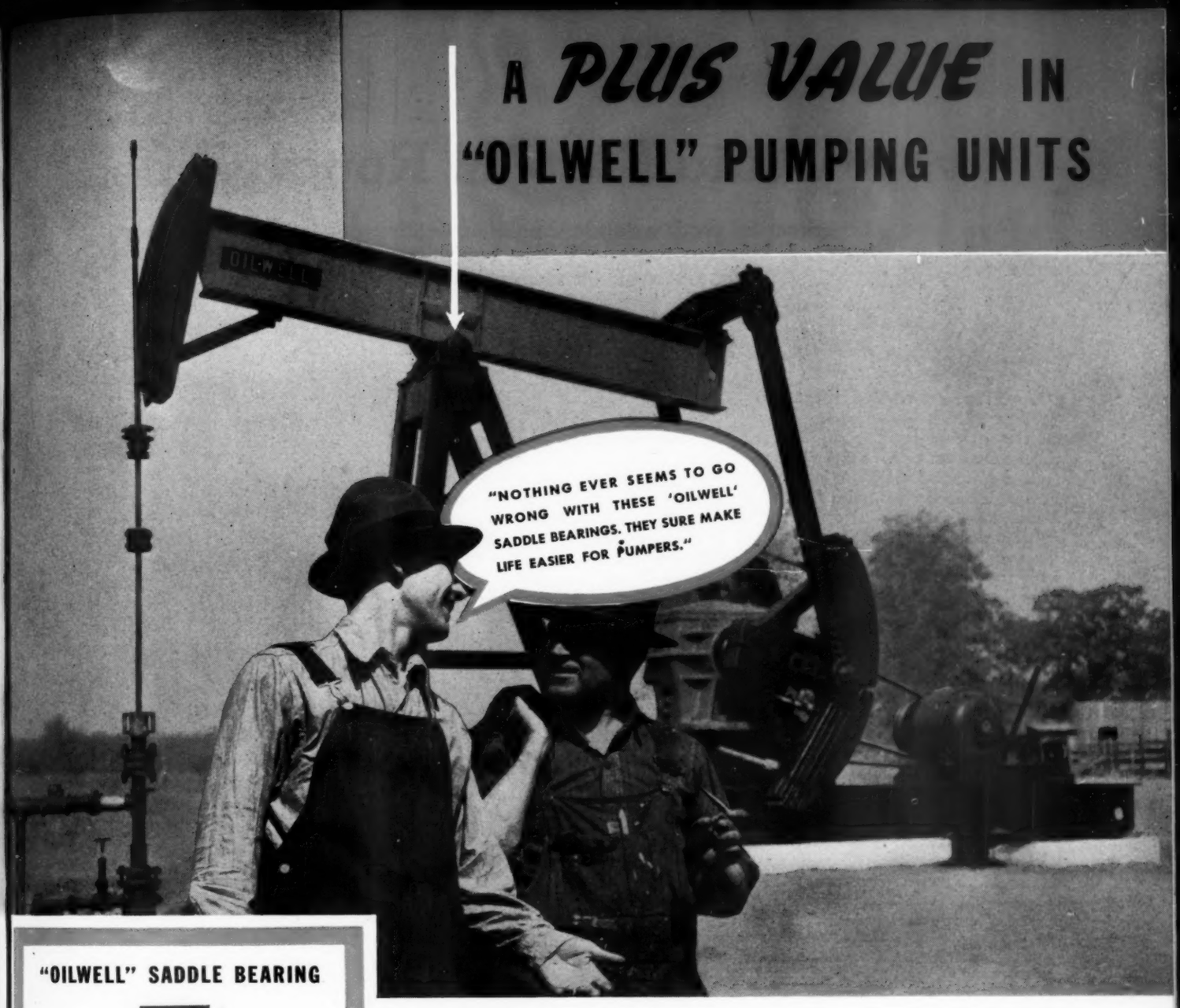
One company avoids this trouble by attaching the steel ladders to its wooden tanks with a flexible bracket that permits wide latitude of movement without affecting either structure. The ladder is set on a concrete base, and held in position by angle-iron brackets fastened to tank hoops by straps looped around the hoop, and loosely held in place with bolts in the straps. This loop is free to revolve around the hoop as far as the bracket can be swung.



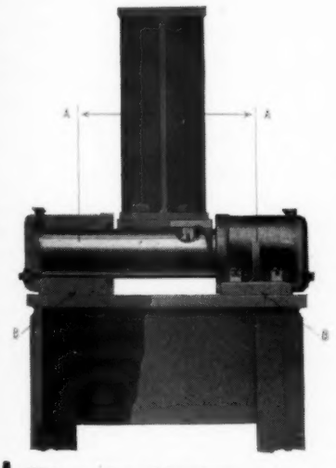
The ladder end of the bracket is bolted to the ladder upright with a single bolt, this being pulled tightly enough to support the ladder against side sway, yet free enough to permit vertical shifting of ladder or stave without imposing added stress on either.

Looped around the tank hoop, and pivoted to the ladder upright by a single bolt, this ladder bracket permits shifting of staves without imposing undue strain on ladder or tank

A *PLUS VALUE* IN "OILWELL" PUMPING UNITS



"OILWELL" SADDLE BEARING



A Wide spacing of bearings.

B Machined bases of the bearing housings rest on machined top of samson post.

TROUBLE-FREE SADDLE BEARINGS

SADDLE BEARINGS in "Oilwell" pumping units are designed for trouble-free performance and long life. They are fully-enclosed, oil-bath, bronze-bushed bearings with oil seals making them dust-proof and weather-proof.

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Laws of Fluid Flow In Rough Pipes

Experimental work extends the determination of friction factor, f, into the region of flow conditions of existing high-pressure transmission lines

PART 4

By J. NIKURADSE

Perhaps no single work, since Weymouth's, has contributed so much of practical value to the knowledge of flow conditions in pipe lines as this paper by Nikuradse. Appearing in *Forschungsheft*, publication of Verein Deutsch Ingenieurs (German Society of Engineers) in 1932, it has been unavailable to American engineers except in the German version. Publication, even seven years after its appearance in Germany, is justified as an answer to the many requests from engineers in this country who desire to avail themselves of the data contained herein.

Due acknowledgment is hereby given to the Panhandle Eastern Pipe Line Company, 90 Broad Street, New York, New York, for permission to publish the English translation of the paper.

3. Power curve. Even if equation (13) or (23) throws sufficient light on the velocity distribution, it is at times convenient to have a power formula as an approximation. As is known, Prandtl[17] formerly concluded from the Blasius resistance curve, by considering the dimensions, that the velocity u near the wall in a turbulent flow changes with the 1/7 power of the distance from the wall, so that the equation:

$$u = a\, y^{\frac{1}{7}} \quad \ldots\ldots\ldots \quad (25)$$

holds good, where a is a constant for every velocity profile. It should be expressly noted that the exponent 1/7 can be used only for smooth pipes within the range of the Blasius resistance curve, (to $Re = 10^5$). For larger Reynolds Numbers, the exponent decreases to 1/10, as was shown by our previous experiments[18]. In rough tubes, however, the relations are quite different; in this case, the exponent increases from 1/7 to 1/4 with increasing relative roughness in the range tested by us.

If the velocity, wall distance, and the shearing stress velocity, v^*, are made nondimensional, equation (25) can be written thus:

$$\frac{u}{v^*} = \phi = C\left(\frac{yv^*}{\nu}\right)^n = C\eta^n$$

in which, according to equation (25), $n = 1/7$. Therefore,

$$\log \phi = \log C + n \log \eta \quad \ldots \quad (26).$$

Therefore, if one plots $\log \phi$ as a function of $\log\eta$, this will result in a straight line with the slope, n. This relation has been reproduced in Fig. 15 for various relative roughnesses and also for a velocity distribution in a smooth pipe. All velocity distributions in rough pipes, shown in this graph, are in the range of the quadratic resistance curve. It can be seen from this graph, that the exponent n increases from 0.133 to 0.238 in the investigated range of the relative roughness; for the plotted profile in the smooth pipe, $n = 0.116$.

In order to find out how the exponent n changes at a constant relative roughness with the Reynolds Number, we have used for the relative roughness $r/k = 126$, and re-determined for various Reynolds Numbers, $\log \phi$ as a function of $\log\eta$. It was established that the change of the inclination in the straight line was very slight with the Reynolds* Number. The smallest Reynolds Numbers plotted are in range I of the resistance curve formerly defined, where the coefficient of resistance λ is the same as in the case of the smooth pipe. The next larger Reynolds Numbers lie in range II (transitional region), and the largest lies in range III (quadratic resistance curve). In the case of Fig. 15, it is shown that the points in the tube center show a deviation from the power curves.

4. Prandtl's mixing path. The well-known quantity, introduced by Prandtl[19] for turbulent shearing stress is written:

$$\frac{\tau}{\rho} = l^2 \left|\frac{du}{dy}\right| \frac{du}{dy}. \quad \ldots\ldots \quad (27a)$$

The determination of the mixing path from the velocity profiles is facilitated by equation (27a):

$$l = \sqrt{\frac{\tau}{\rho}} : \left(\frac{du}{dy}\right)^2 \quad \ldots \quad (27b)$$

consequently, the temporary shearing stress is connected with the shearing stress at the wall, τ_o, by means of the linear relation:

$$\tau = \tau_0\left(1 - \frac{v}{r}\right) \quad \ldots\ldots \quad (28)$$

For the determination of the mixing path depending on the wall distance, according to equation (27b), du/dy was determined graphically from the velocity distribution. In the vicinity of the tube axis, this determination becomes somewhat difficult, since in this case τ/ρ as well as du/dy is very small. In a former article[20] it was demonstrated in detail how to proceed to obtain l in the most accurate possible manner.

In Fig. 16 is shown the nondimensional mixing path distribution obtained in this manner for large Reynolds Numbers, which lie in the range of the quadratic resistance curve. The solid curve is that curve obtained from measurements in the smooth pipe, which, according to Prandtl, may be calculated by the equation:

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[20] *J. Nikuradse:* Gesetzmäszigkeiten der turbulenten Strömung in glatten Rohren. VDI-Forsch.-Heft 356 (1932).

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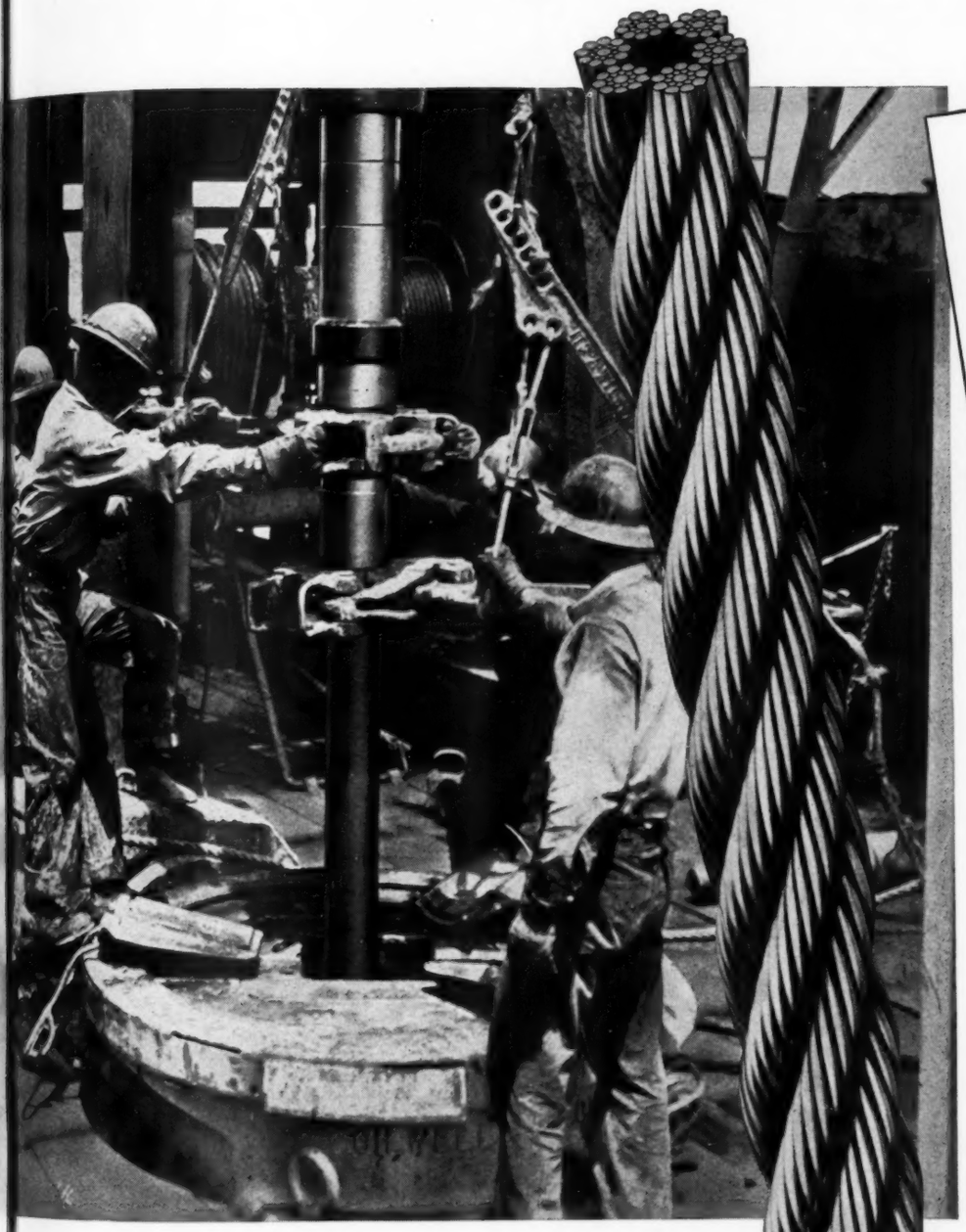

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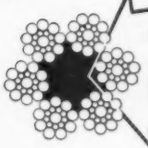

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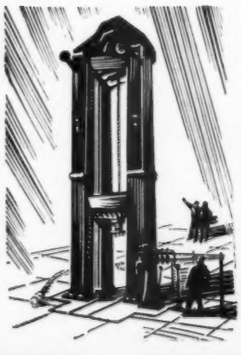

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TABLE 4

$\bar{u}$ cm/s	ν cm²/s	$\frac{dp}{dx}$ dyn/cm³	lg *Re*	lg (100 λ)	$\frac{1}{\sqrt{\lambda}} - 2\lg r/k$	lg $\frac{v_* k}{\nu}$	$\frac{2{,}83}{\sqrt{\lambda}} - C$	$\frac{\bar{u}}{U}$
				$r/k = 126$				
		$k = 0{,}01$ cm		$d = 2{,}474$ cm	lg $r/k = 2{,}10$			
22,8	0,0132	0,00422	3,630	0,594	0,85	0,08279	5,93	0,795
25,2	0,0132	0,00506	3,675	0,588	0,88	0,12418	6,01	0,790
27,7	0,0132	0,00598	3,715	0,576	0,94	0,16047	6,20	0,794
30,7	0,0132	0,00715	3,760	0,566	1,01	0,19700	6,39	0,799
34,4	0,0132	0,00870	3,810	0,552	1,10	0,24055	6,61	0,798
36,3	0,0132	0,00996	3,833	0,564	1,02	0,26951	6,41	0,800
41,8	0,0132	0,01210	3,895	0,532	1,27	0,31175	7,15	0,805
44,8	0,0132	0,01355	3,925	0,515	1,33	0,33686	7,30	0,806
47,5	0,0132	0,01480	3,950	0,503	1,40	0,35603	7,50	0,809
49,2	0,0132	0,01570	3,965	0,498	1,43	0,36922	7,60	0,810
55,2	0,0132	0,0195	4,015	0,491	1,48	0,41497	7,70	0,810
68,8	0,0132	0,0289	4,111	0,471	1,61	0,50996	8,10	0,816
83,7	0,0132	0,0408	4,196	0,451	1,75	0,57542	8,50	0,818
98,2	0,0132	0,0532	4,265	0,435	1,85	0,63347	8,80	0,818
114,0	0,0132	0,0713	4,330	0,424	1,93	0,69636	9,04	0,824
129,5	0,0132	0,0900	4,386	0,415	1,99	0,74741	9,18	0,825
136,5	0,0132	0,0990	4,425	0,412	2,03	0,75669	9,24	0,823
157,5	0,0132	0,1287	4,470	0,400	2,10	0,82543	9,47	0,824
167,0	0,0132	0,1432	4,496	0,396	2,14	0,84880	9,55	0,829
173,0	0,0132	0,1550	4,511	0,400	2,11	0,86570	9,52	0,828
189	0,0133	0,1823	4,550	0,393	2,15	0,90200	9,61	0,825
223	0,0132	0,253	4,620	0,392	2,16	0,97267	9,64	0,829
266	0,0132	0,360	4,697	0,391	2,17	1,04844	9,65	0,828
307	0,0132	0,488	4,760	0,400	2,11	1,11428	9,53	0,824
352	0,0132	0,646	4,820	0,403	2,09	1,17609	9,46	0,825
420	0,0128	0,930	4,910	0,408	2,05	1,26811	9,30	0,826
500	0,0128	1,335	4,985	0,414	2,01	1,34674	9,20	0,823
590	0,0128	1,896	5,057	0,422	1,95	1,42259	9,04	0,824
683	0,0128	2,555	5,121	0,424	1,93	1,48785	9,00	0,825
755	0,0128	3,164	5,164	0,430	1,90	1,53656	8,92	0,820
		$k = 0{,}04$ cm		$d = 9{,}92$ cm	lg $r/k = 2{,}10$			
121	0,0117	0,0200	4,950	0,430	1,90	1,37694	8,92	0,825
132	0,0117	0,0243	5,049	0,432	1,88	1,41896	8,85	0,821
124	0,0117	0,0206	5,021	0,415	2,00	1,38346	9,18	0,821
149	0,0117	0,0302	5,100	0,422	1,95	1,46627	9,05	0,823
159	0,0117	0,0347	5,130	0,422	1,93	1,49665	9,00	0,821
178	0,0117	0,0440	5,179	0,430	1,90	1,54876	8,90	0,823
185	0,0117	0,0475	5,196	0,430	1,91	1,56467	8,92	0,821
198	0,0117	0,0548	5,225	0,435	1,87	1,59550	8,25	0,822
198	0,0117	0,0544	5,225	0,430	1,90	1,59329	8,90	0,819
210	0,0117	0,0620	5,250	0,436	1,85	1,62221	8,80	0,822
222	0,0117	0,0696	5,274	0,438	1,84	1,64738	8,76	0,820
230	0,0117	0,0747	5,290	0,438	1,84	1,69373	8,75	0,822
181	0,0088	0,0460	5,310	0,436	1,85	1,68124	8,77	0,818
190	0,0088	0,0510	5,330	0,439	1,83	1,70415	8,72	0,820
199	0,0088	0,0560	5,350	0,439	1,83	1,72428	8,70	0,820
206	0,0088	0,0609	5,366	0,444	1,80	1,74273	8,67	0,818
219	0,0088	0,0687	5,393	0,444	1,80	1,76938	8,62	0,820
235	0,0088	0,0794	5,423	0,446	1,79	1,80003	8,60	0,820
244	0,0088	0,0857	5,432	0,447	1,78	1,81690	8,60	0,816
253	0,0088	0,0930	5,455	0,450	1,76	1,83315	8,51	0,818
265	0,0088	0,1025	5,476	0,452	1,74	1,85491	8,48	0,817
281	0,0088	0,1140	5,501	0,447	1,78	1,87795	8,53	0,819
301	0,0081	0,1300	5,525	0,447	1,78	1,94300	8,53	0,816
326	0,0081	0,1533	5,560	0,450	1,76	1,98000	8,51	0,818
350	0,0089	0,175	5,591	0,450	1,75	1,96614	8,46	0,820
371	0,0089	0,201	5,616	0,453	1,74	1,99739	8,42	0,815
406	0,0089	0,238	5,655	0,447	1,78	2,03383	8,55	0,818
424	0,0089	0,261	5,675	0,450	1,75	2,05346	8,47	0,817
458	0,0089	0,301	5,708	0,445	1,78	2,08600	8,56	0,814
488	0,0089	0,347	5,736	0,452	1,74	2,11661	8,45	0,818
511	0,0089	0,374	5,756	0,445	1,79	2,13194	8,58	0,811
535	0,0089	0,410	5,775	0,445	1,79	2,15259	8,58	0,819
538	0,0085	0,420	5,798	0,450	1,75	2,17754	8,48	0,817
581	0,0085	0,490	5,831	0,450	1,77	2,21005	8,51	0,819
586	0,0085	0,494	5,835	0,446	1,79	2,21245	8,58	0,816
642	0,0085	0,598	5,874	0,450	1,75	2,25310	8,48	0,817
672	0,0085	0,650	5,894	0,447	1,78	2,27184	8,55	0,819
738	0,0085	0,791	5,935	0,450	1,75	2,30963	8,48	0,816
783	0,0085	0,877	5,961	0,444	1,80	2,33746	8,60	0,818
800	0,0085	0,927	5,970	0,449	1,77	2,34928	8,51	0,817
832	0,0135	1,000	5,987	0,447	1,78	2,16435	8,54	0,818

Tables 4 and 5 show experimental data for r/k of 126 and 60, respectively

TABLE 5

$\bar{u}$ cm/s	ν cm²/s	$\frac{dp}{dx}$ dyn/cm³	lg *Re*	lg (100 λ)	$\frac{1}{\sqrt{\lambda}} - 2\lg r/k$	lg $\frac{v_* k}{\nu}$	$\frac{2{,}83}{\sqrt{\lambda}} - C$	$\frac{\bar{u}}{U}$
				$r/k = 60$				
		$k = 0{,}02$ cm		$d = 2{,}434$ cm	lg $r/k = 1{,}78$			
23,8	0,0128	0,00466	3,653	0,593	1,50	0,417	7,86	0,791
26,3	0,0128	0,00548	3,700	0,577	1,59	0,450	8,15	0,795
28,9	0,0128	0,00650	3,740	0,571	1,62	0,529	8,19	0,796
32,0	0,0128	0,00780	3,785	0,560	1,69	0,526	8,42	0,798
37,5	0,0128	0,01030	3,851	0,544	1,79	0,588	8,68	0,801
39,0	0,0128	0,01084	3,869	0,531	1,83	0,600	8,78	0,804
42,7	0,0128	0,0124	3,909	0,512	1,99	0,627	9,27	0,805
46,8	0,0128	0,0150	3,949	0,512	1,99	0,668	9,27	0,802
52,0	0,0128	0,0182	3,996	0,507	2,02	0,711	9,35	0,808
60,0	0,0128	0,0236	4,057	0,494	2,10	0,767	9,57	0,808
64,6	0,0128	0,0270	4,090	0,490	2,13	0,797	9,66	0,806
76,2	0,0128	0,0379	4,161	0,494	2,10	0,871	9,57	0,813
90,4	0,0128	0,0526	4,236	0,487	2,15	0,942	9,73	0,810
102,5	0,0128	0,0676	4,290	0,487	2,15	0,999	9,73	0,811
129,0	0,0128	0,1055	4,391	0,481	2,18	1,093	9,77	0,814
135,6	0,0128	0,1190	4,412	0,489	2,14	1,119	9,68	0,810
171,0	0,0128	0,1890	4,512	0,490	2,13	1,220	9,67	0,810
182,5	0,0128	0,2142	4,540	0,487	2,15	1,248	9,73	0,811
188,0	0,0128	0,2334	4,553	0,498	2,07	1,265	9,47	0,808
187,0	0,0120	0,2280	4,580	0,493	2,11	1,288	9,62	0,810
200,0	0,0120	0,2690	4,609	0,507	2,02	1,324	9,36	0,807
214	0,0118	0,3062	4,654	0,504	2,04	1,361	9,38	0,810
224	0,0118	0,338	4,665	0,507	2,02	1,380	9,35	0,810
242	0,0118	0,397	4,699	0,509	2,00	1,415	9,28	0,808
262	0,0116	0,474	4,740	0,517	1,95	1,462	9,17	0,806
280	0,0116	0,544	4,769	0,520	1,94	1,491	9,12	0,807
302	0,0114	0,645	4,813	0,528	1,89	1,537	8,97	0,805
332	0,0114	0,777	4,849	0,526	1,90	1,576	8,99	0,805
399	0,0114	1,165	4,930	0,543	1,80	1,664	8,76	0,804
421	0,0114	1,270	4,954	0,534	1,85	1,683	8,87	0,801
508	0,0114	1,890	5,034	0,543	1,79	1,769	8,68	0,803
671	0,0114	3,30	5,155	0,543	1,79	1,890	8,68	0,802
566	0,0114	2,36	5,083	0,545	1,78	1,818	8,67	0,799
717	0,0114	3,83	5,185	0,550	1,75	1,923	8,58	0,800
795	0,0114	4,57	5,231	0,537	1,83	1,961	8,78	0,802
		$k = 0{,}08$ cm		$d = 9{,}8$ cm	lg $r/k = 1{,}78$			
101	0,0132	0,0182	4,875	0,535	1,84	1,603	8,83	0,802
113	0,0132	0,0227	4,924	0,534	1,85	1,651	8,87	0,805
121	0,0132	0,0264	4,954	0,542	1,80	1,685	8,76	0,803
131	0,0114	0,0306	5,052	0,535	1,84	1,780	8,86	0,800
145	0,0132	0,0380	5,033	0,540	1,81	1,763	8,77	0,800
157	0,0114	0,0452	5,130	0,545	1,78	1,865	8,67	0,798
192	0,0127	0,0681	5,170	0,550	1,75	1,906	8,58	0,800
203	0,0127	0,0755	5,196	0,547	1,77	1,928	9,56	0,798
220	0,0127	0,0933	5,230	0,568	1,64	1,965	8,27	0,800
235	0,0127	0,1024	5,258	0,551	1,74	1,996	8,57	0,800
249	0,0127	0,1158	5,283	0,555	1,71	2,021	8,47	0,801
266	0,0127	0,1310	5,312	0,551	1,74	2,049	8,57	0,798
272	0,0119	0,1383	5,350	0,555	1,71	2,089	8,47	0,802
311	0,0119	0,1786	5,408	0,550	1,75	2,143	8,58	0,800
358	0,0119	0,2400	5,470	0,555	1,72	2,207	8,48	0,803
371	0,0116	0,2500	5,497	0,543	1,69	2,228	8,68	0,801
387	0,0116	0,278	5,515	0,551	1,74	2,252	8,57	0,799
418	0,0116	0,323	5,549	0,550	1,75	2,286	8,58	0,800
424	0,0116	0,338	5,554	0,558	1,70	2,294	8,46	0,799
445	0,0116	0,366	5,575	0,551	1,74	2,311	8,57	0,799
471	0,0116	0,411	5,600	0,550	1,75	2,336	8,58	0,801
495	0,0116	0,464	5,621	0,560	1,69	2,362	8,42	0,798
499	0,0116	0,454	5,625	0,543	1,79	2,358	8,69	0,804
514	0,0115	0,481	5,641	0,543	1,79	2,375	8,69	0,800
531	0,0115	0,521	5,655	0,550	1,75	2,391	8,58	0,798
535	0,0115	0,531	5,659	0,551	1,74	2,396	8,57	0,802
548	0,0115	0,567	5,668	0,560	1,69	2,410	8,42	0,798
576	0,0115	0,617	5,691	0,553	1,73	2,428	8,55	0,801
609	0,0115	0,689	5,714	0,551	1,74	2,453	8,57	0,800
656	0,0115	0,810	5,748	0,558	1,70	2,488	8,46	0,797
670	0,0115	0,830	5,757	0,550	1,75	2,494	8,58	0,802
721	0,0115	0,966	5,789	0,551	1,74	2,526	8,57	0,800
840	0,0120	1,290	5,836	0,547	1,77	2,570	8,65	0,802
896	0,0120	1,505	5,865	0,555	1,72	2,603	8,49	0,799
770	0,0092	1,100	5,914	0,553	1,73	2,648	8,54	0,801
774	0,0092	1,105	5,916	0,550	1,75	2,658	8,58	0,798
836	0,0092	1,298	5,945	0,551	1,74	2,686	8,57	0,802
860	0,0092	1,380	5,962	0,555	1,71	2,699	8,47	0,799

PRECISION

Another reason why Mission Pump Parts deliver such outstanding performance . . .

PRECISION means dependability—it means long, uniform, trouble-free life for every part—it means safe, low-cost operation *all* the time. Knowing the importance of precision, Mission takes exceptional care to make every part as nearly perfect as modern precision testing instruments will allow.

Take Mission Pistons for Example:

Every operation in making a Mission Piston is a precision operation. High grade alloy steel of *exactly* the right analysis is forged into tough, homogeneous piston bodies. These bodies are heat treated in a modern heat treating plant equipped with the most precise controls money can buy.

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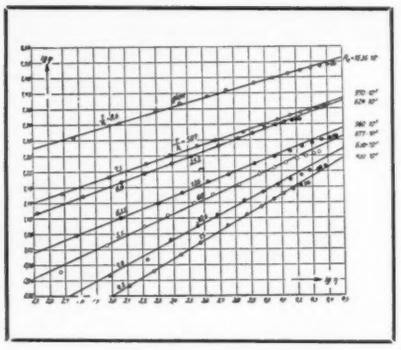

Fig. 15

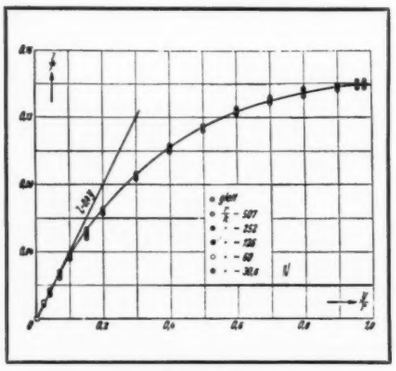

Fig. 16

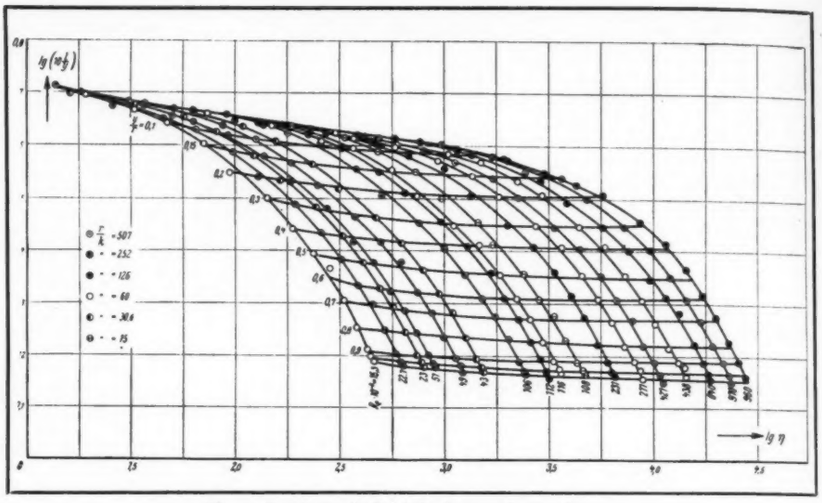

Fig. 17—Log (10 l/y) depends on log η

$$\frac{l}{r} = 0.14 - 0.08\left(1 - \frac{y}{r}\right)^2 - 0.06\left(1 - \frac{y}{r}\right)^4 \quad . \quad (29).$$

The mixing path distribution of the rough pipes, therefore, is the same as for the smooth pipe. From this fact one may conclude that the turbulence mechanism, apart from a thin layer, close to the wall, is independent of the nature of the wall.

In order to represent clearly the change in the distribution of the mixing path with the Reynolds Number and with the relative roughness, log (10 l/y) is plotted in Fig. 17, dependent on $\log \eta = \log \frac{v^* v.}{\nu}$

Each curve corresponds to a certain Reynolds Number, which is shown in the graph as a parameter. As l/y is largest in the vicinity of the wall, the points near the wall lie highest in the graph, and those at the pipe axis are the lowest. The curves running from left to right are connecting points of similar y/r values. For such Reynolds Numbers and relative roughnesses where there is no viscosity effect, the latter curves run parallel to the axis of abscissas. This parallelism does not exist for small Reynolds Numbers and small relative roughnesses, therefore in this case the effect of viscosity is markedly noticeable. From Figs. 16 and 17, therefore, it again appears that with large Reynolds Numbers, where a viscosity effect does not exist, the mixing path distribution and, therefore, the turbulence mechanism are independent of the Reynolds Number and of the relative roughness.

5. Relation between the medium and maximum velocities. According to equation (16b):

$$U = v^* (A + B \log r/k) \quad . \quad (16c)$$

and with equation (17b):

$$\bar{u} = v^*\left(A + B \log \frac{r}{k} - \beta\right) \quad . \quad (30)$$

in which B is a constant for all Reynolds Numbers and relative roughnesses

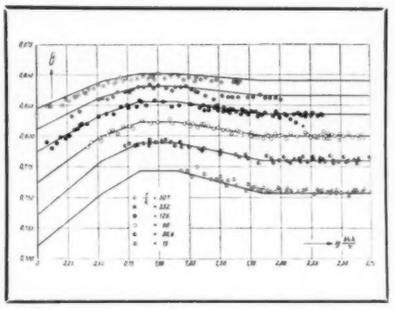

Fig. 18

(B = 5.75), whereas A is contant only in the range of the quadratic resistance curve, and otherwise varies with $\frac{(v^* k)}{\nu}$; furthermore $\beta = 3.75$. By dividing equation (30) by (16c), we have:

$$\frac{\bar{u}}{U} = \frac{A + B \log \frac{r}{k} - \beta}{A + B \log \frac{r}{k}} \quad . \quad (31)$$

Formerly, in accordance with equations (21a) to (21e), A was found as a function of $\frac{v^* k}{\nu}$. Consequently, we have from equation (31), at the constant relative roughness r/k, the relation:

$$\frac{\bar{u}}{U} = f\left(\log \frac{v^* k}{\nu}\right) \quad . \quad (32)$$

which is shown in Fig. 18, in which the individual curves correspond to various relative roughnesses. The curves were calculated according to equation (31), and the plotted points are the values listed in Tables 2 to 7.

EDITOR'S NOTE: This article will be concluded in a forthcoming issue.

Nomenclature For Tables 8 to 13

u = temporary velocity; y = distance from the wall; $\mathrm{Re} = \frac{\bar{u} d}{\gamma}$ Reynolds Number; $\bar{u}$ = mean velocity; d = diameter of pipe; γ = kinematic viscosity; $v^* = \sqrt{\frac{\tau_o}{\rho}}$ = shearing stress velocity; τ_o = shearing stress at the wall; ρ = density; k = mean elevation of roughness; r/k = relative roughness.

In these tables, the comma is equivalent to a decimal point, i.e., 0,00496 is 0.00496. The symbol, log, for logarithm appears as lg.

Electric Power for Oil-Well Pumping in East Texas

Recent installations indicate that 10-hp. motors are generally ample to take care of present and future requirements

By J. E. MOODY

Industrial Engineer, Southwestern Gas and Electric Company, Shreveport, Louisiana

THE electric motor has long been used as a prime mover for the production of oil. During recent years, marked improvements have been made to the electric motor used for this purpose. When electric power was first applied to oil-well pumping, there were two distinct operations to be performed by permanent equipment—pumping and well servicing. The motor developed to perform these two functions of highly varied characteristics was expensive and accomplished the purpose only through sacrifice in efficiency.

Today pumping is the only operation performed by equipment placed at the well, and the highly efficient, simple and inexpensive squirrel cage motor solves the problem. It is admirably suited to present-day pumping units and the combination operating together usually results in a high overall efficiency. Installation expenses are reduced to a minimum as, in most instances, the motor requires no additional foundation inasmuch as it is bolted to the bed plate of the unit. Control equipment is simple, and automatic operation is easily obtained by the addition of an inexpensive time switch. If the motor is installed in a house, the standard open-type motor may be used. If not, a motor may be obtained in the weatherproof type at a cost slightly higher than that of the open motor type. Explosion-proof motors may be obtained for operation in explosive atmospheres. Each motor modification has contributed to the development of a highly refined and specialized "tool" to meet the exacting requirements of modern industry. Motors in use today on modern pumping equipment may include one of the following:

1. Single-rated, single-speed, normal-torque.
2. Single-rated, single-speed, high-torque.
3. Star Delta, double-rated, single-speed.
4. Double-rated, two-speed, constant-torque.
5. Double- or triple-rated, single-speed.

The first two are the most generally used. The single-rated, single-speed, normal-torque motor is of the general purpose classification, and many of these motors are in operation on well-pumping installations. Should automatic time switch operation be used, however, the high-torque motor is preferable. This is an added safety feature as the extra torque is necessary at times to get the well started. The cost of this motor is about 8 percent more than the normal-torque motor. The selection of other types and modifications are merely matters of opinion. The starting or control equipment for these motors consists merely of a fused disconnect switch and a magnetic contactor and push button station. All these motors may be obtained in open or weatherproof types.

Standard electric motor synchronous speeds in use on pumping equipment are 1800, 1200, 900, and 720 r.p.m. The full load speeds are slightly lower by approximately 3 to 4 percent and are the speeds to use in calculating pulley ratios. The gear and pulley ratios of most pumping units are such that a 1200 r.p.m. motor is generally used. A motor of this speed is less expensive and slightly more efficient than motors of lower speeds.

Opinions vary as to the size motor to use. The actual power required, in

(Continued on Page 46)

J. E. MOODY

received his B.S. degree in electrical engineering in 1926 from Alabama Polytechnic Institute (Auburn), after which he accepted a position with the General Electric Company at Lynn, Massachusetts—He completed their student engineering training course and subsequently was employed in the company's induction motor design engineering department at Lynn and then in the industrial engineering department at their general office in Schenectady, New York — From October, 1929, to October, 1932, he was sales engineer for the General Electric Company—In October, 1932, he left the General Electric Company and from then until 1936 served in various capacities with several companies throughout the East—In March, 1936, he became associated with the Southwestern Gas and Electric Company in the Industrial Engineering Department — His principal work, during this period, has been in the application of electric power in the various branches of the petroleum industry.

TABLE I

Electric Power Cost Per Month

Calculations based on 0.814 kw-hr. per bbl.

Barrels pumped per month	Total kw-hr.	Cost per month in dollars at various rates for power in cents per kw-hr.				
		2	1.5	1.25	1	0.9
400	325	$ 6.50	$ 4.88	$ 4.06	$ 3.25	$ 2.93
450	366	7.32	5.49	4.58	3.66	3.29
500	407	8.14	6.11	5.09	4.07	3.66
550	447	8.94	6.71	5.60	4.47	4.02
600	488	9.76	7.32	6.10	4.88	4.39
650	529	10.58	8.94	6.61	5.29	4.76

AVOID *Frozen* CAPITAL IN PRIVATE GENERATING FACILITIES

This Mid-Continent pumping well is bringing its operator BIGGER returns . . . and his power investment has been turned into available capital! Utility Electric Power, of course.

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EFFICIENT POWER WITHOUT CAPITAL INVESTMENT! Operators everywhere are getting the use of more capital funds than ever before, with Utility Electric Power. For this modern power backs an outstanding record of performance with the greatest profit advantage known—the assumption of power capital investment by the power company!

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POWER EFFICIENCY GOES UP, with less downtime . . . instant starting and stopping. Power charges go *down*—with Utility Electric Power, you pay only for power used. Smooth, silent, extremely flexible, Utility Electric Power makes equipment more portable—gives it higher salvage value, longer life.

IT COSTS YOU NOTHING to get details on how Utility Electric Power releases your power capital dollars for use elsewhere. Simply consult your nearest electric power company—today—for facts that may show you the way to modern profits . . . modern efficiency!

The Petroleum Electric Power Association is the outgrowth of a desire on the part of electric power companies to render greater service, through cooperative effort, to the Petroleum Industry.

Use Utility Electric Power

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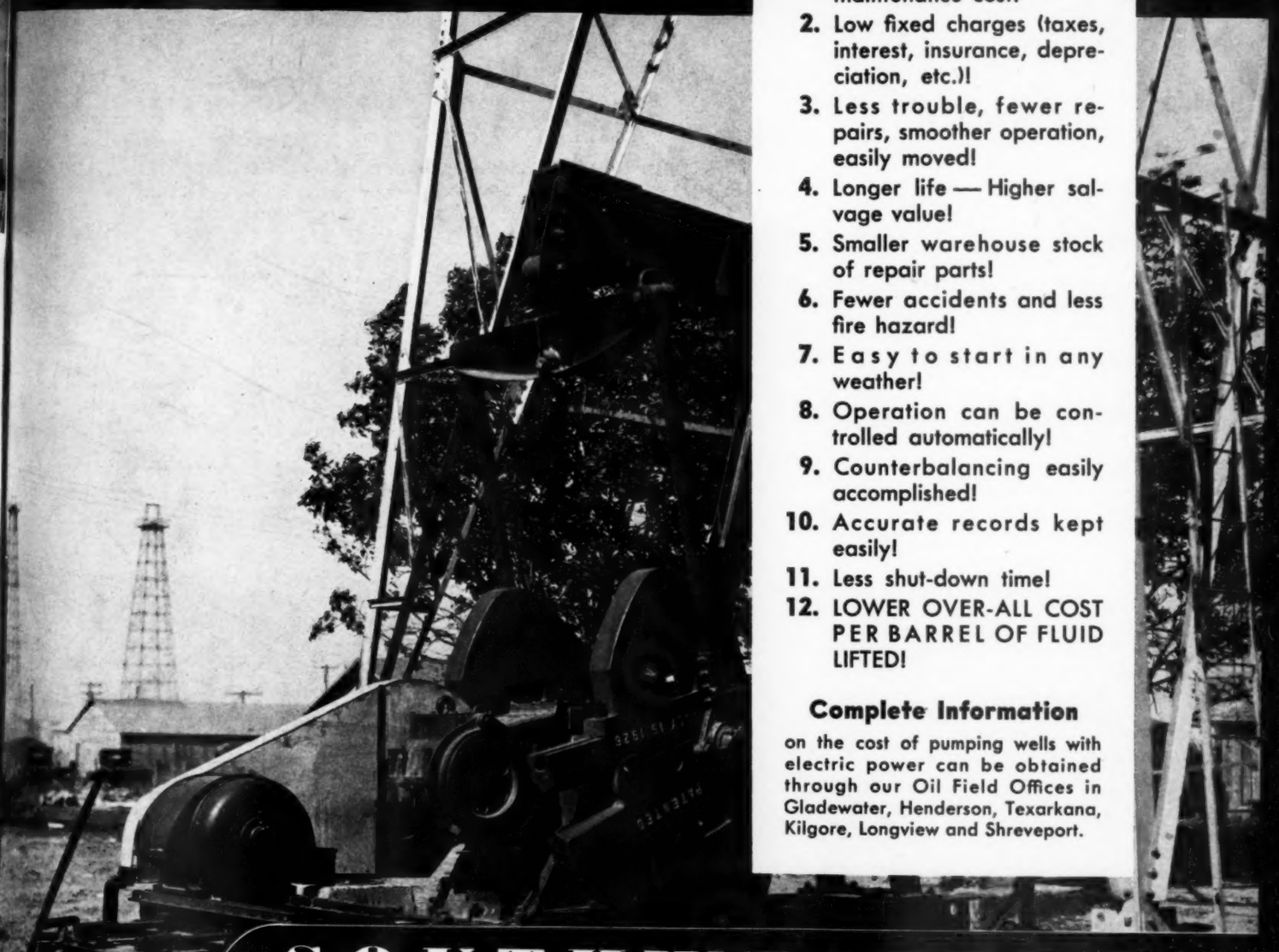
12 REASONS WHY *Purchased Electric Power is Preferred in the East Texas Oil Fields*



1. Low first cost and low maintenance cost!
2. Low fixed charges (taxes, interest, insurance, depreciation, etc.)!
3. Less trouble, fewer repairs, smoother operation, easily moved!
4. Longer life — Higher salvage value!
5. Smaller warehouse stock of repair parts!
6. Fewer accidents and less fire hazard!
7. Easy to start in any weather!
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9. Counterbalancing easily accomplished!
10. Accurate records kept easily!
11. Less shut-down time!
12. LOWER OVER-ALL COST PER BARREL OF FLUID LIFTED!

Complete Information

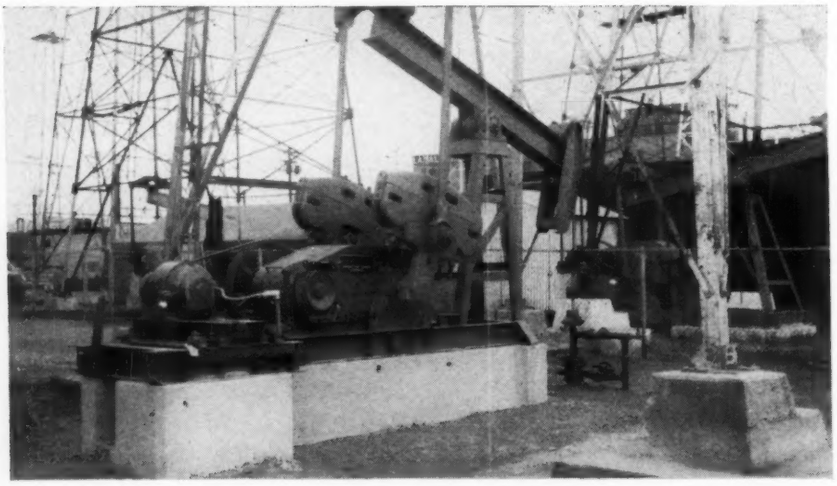
on the cost of pumping wells with electric power can be obtained through our Oil Field Offices in Gladewater, Henderson, Texarkana, Kilgore, Longview and Shreveport.

SOUTHWESTERN
GAS & ELECTRIC COMPANY

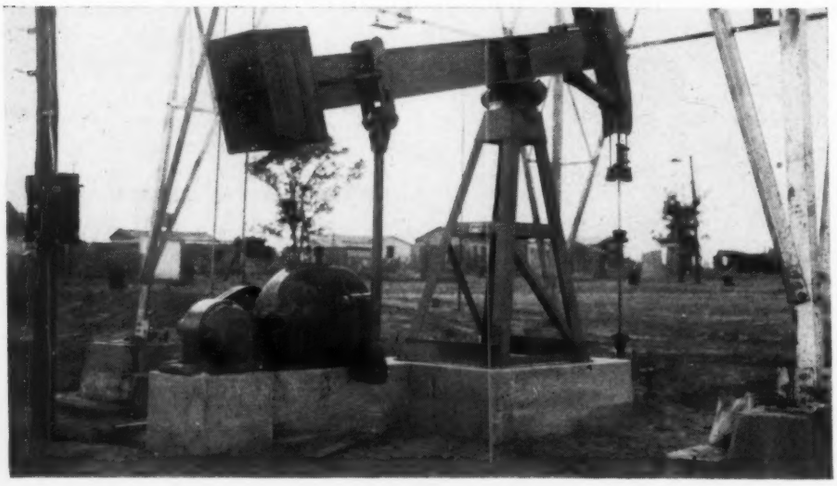
TABLE 2

Lease	Survey	Total wells	Total kw-hr. per month	Power per well per month, kw-hr.
Cox	Penny	2	320	160
Bradford	Ximines	4	760	190
Hughey	Van Winkle	3	1130	377
Knowles	Van Winkle	7	1340	191
Hughey	Van Winkle	3	160	53
Faircloth	Van Winkle	3	1181	394
Barton	Van Winkle	2	274	137
Thomas	Van Winkle	10	1480	148
Reeves	Hooper	3	540	180
Wilson	Martin	6	1380	230
Phillips	Harrell	1	420	420
Laird	Van Winkle	5	1720	344
Block 153	Van Winkle	2	440	220
Block 117	Van Winkle	2	240	120
King	Van Winkle	1	220	220
Green	Van Winkle	5	400	80
Knowles	Van Winkle	6	760	127
Florence	Van Winkle	4	500	125
Holt	Clark	2	720	360
King	Chism	3	440	147
Douglas	Chism	1	120	120
Block 175	Van Winkle	2	769	385
Walker	Friar	3	1600	533
Mackey	Pineda	6	1360	227
Waddell	Hokit	1	560	560
Laird	McKim	3	920	307
Block 138	Van Winkle	4	800	200
Wells	Hobson	1	160	160
Miller	Davis	6	2400	400
Wooley	Martin	8	4920	615

Electric motors are welcomed in townsite pumping because of their quiet operation



Well being pumped by a 7½-hp. motor



A 15-hp., 440-volt motor on Tennery lease of Arkansas Fuel Oil Company

(Continued from Page 43)

most instances, is small and many installations now in operation are overmotored. In addition to other factors, the speed at which the unit will operate should be given consideration in making the selection, as the horsepower required is a function of the time in which the job is to be done. Theoretically, a well pumping at the rate of 5 bbl. per hr. will require approximately one-half the power as one pumping at the rate of 10 bbl. per hr. It should be remembered that electric motors will operate and deliver their full rated output 24 hours per day, also that they are more efficient when operated at or near the full load rating. Recent installations on the east side of the East Texas field include 7½- and 10-hp. motors. It is the general opinion of most operators that a 10-hp. motor is ample to take care of present and future requirements. On the west side, where it is necessary to handle more fluid because of salt water, the unit is usually operating faster and requires more horsepower. The power need not necessarily be increased greatly, however, as fluid levels are high and it is not required to pump from the bottom. Recent practice is to pump "up the hole," which decreases the power requirement considerably. Most installations have been made using 15- and 20-hp. motors, but recent indications are that 10 hp. is sufficient. In general

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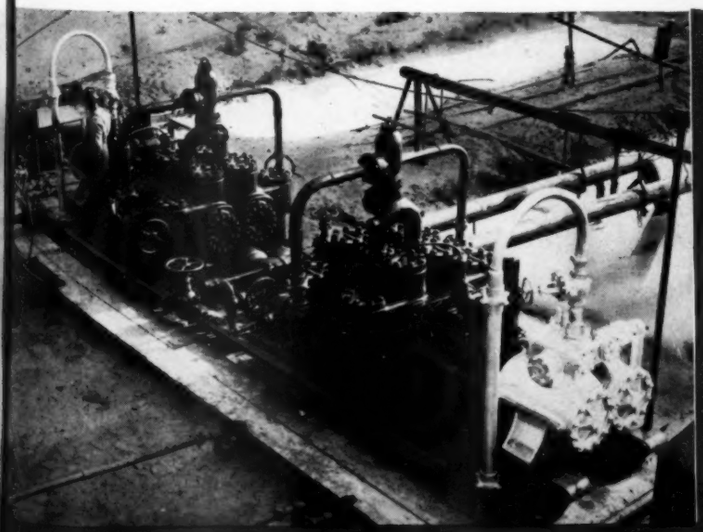

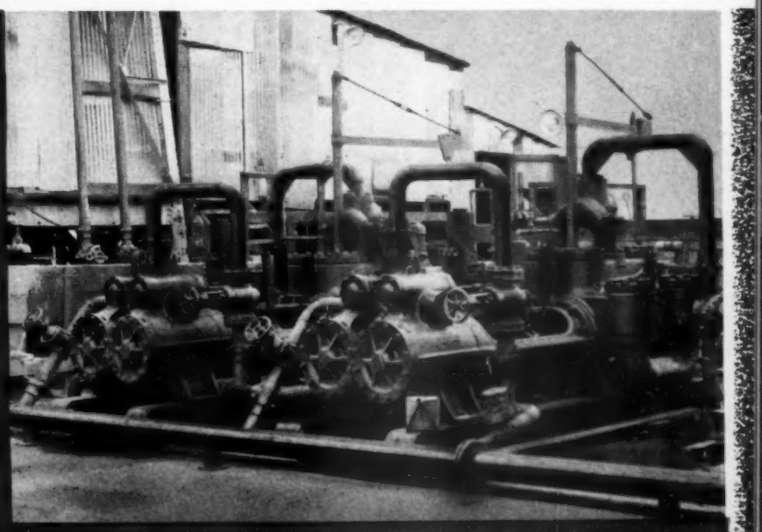

CONTINENTAL

the average power requirement for the field is about 6 to 7 hp. for individual pumping units.

It is desired to know the amount of energy required to pump a volume of oil. From a theoretical standpoint, this may be calculated by assuming a pumping depth of 3600 ft. and the weight of a barrel of crude, 300 lb. Then:

300 lb. $\times$ 3600 ft. = 1,080,000 ft-lb.
1 kw-hr. = 2,655,200 ft-lb.

Energy required to lift 1 bbl. of oil 3600 ft. is, therefore:

$$\frac{1,080,000}{2,655,200} = 0.407 \text{ kw-hr.}$$

This calculation is based on overall efficiency of 100 percent and does not take into consideration influencing factors such as gas in solution, which would tend to decrease the amount of work done. In performing this work, mechanically, the actual power input to the motor will depend upon the overall efficiency. If we assume this to be 50 percent, which appears to be reasonable, the energy per bbl. of oil would be 0.814 kw-hr. This figure compares with a recent test on a well on the east side of the field where actually 0.823 kw-hr. per bbl. was required. This test was conducted on a well where a large unit, having considerable friction, was involved and the overall efficiency was slightly low. As a large percentage of the energy input was required to overcome friction in the large unit, it is to be assumed that less energy will be required using a small unit. In any event the electric power cost is extremely low, as shown in Table 1 giving the cost per month for various amounts of oil pumped in the East Texas field. The rate earned is dependent upon the load factor and the number of kw-hr. purchased.

Table 2 is a list of a few wells now operating in East Texas with electric power. The wells requiring relatively small amounts of energy to produce the allowable are either being agitated by gas in solution or pumped from a high fluid level. This list is given to illustrate the small amount of energy actually required to pump East Texas wells.

The greatest amount of energy required by any one well listed is 615 kw-hr. per month, and at the average rate of 2 cents per kw-hr. would cost $12.30 per month. Under present proration, the energy consumption per well appears to average 325 kw-hr. per month, cost of which at 2 cents per kw-hr. would be $6.50 per month.

Many companies are making generous use of electric power for well pumping in the East Texas oil field.

This well is being produced by a 15-hp., 230-volt motor

Ingenious arrangement of swing and connecting beam permits this motor to pump two wells

Modern motors require no protection from the weather

P 514.121

Motor-Driven Submerged Power Pump Tested in California Fields

Newly developed unit is capable of pumping approximately 250 bbl. of oil per day—Tests made in wells of 3000 to 5000 ft. depth

By WALLACE A. SAWDON
Pacific Coast and Foreign Editor

PRODUCTION in California comes from wells ranging in depths from a few hundred feet to below 13,000 ft. Of the 14,814 present producing wells[1] of this state, 13,098 are on the pump. Although most of the pumping wells are comparatively shallow according to our present conception of deep wells, several in different fields have been pumped from depths below 8000 ft., and the deep wells now flowing will some day have to be produced by artificial means. Regardless of depth, the fact that 88 percent of the producing wells in California are on the pump indicates the importance of pumping technique; and as this percentage of pumping wells is probably less than for many other oil-producing areas, the development of pumping equipment to provide greater economy and reduced maintenance is of universal interest.

The sucker-rod-actuated type of oil-well pump has been in service for many years but during the last decade several rodless pumps have been developed.

In all cases a period of experimentation has preceded the introduction of such equipment to the industry; by exhaustive tests that have aided in perfecting the designs, equipment of proved performance has resulted. The latest of these rodless pumping devices has now emerged from a series of tests that has covered the last two years. This pumper is an electrically operated power unit placed at the lower end of the tubing to actuate a conventional oil-well pump of any make attached below the unit.

Production conditions are usually more favorable to one type of rodless pump than to another. Considerations must be taken of the volume of oil to be produced, the gas-oil ratio, percentage of water, paraffin trouble, bottom-hole temperatures, sand conditions, maintenance expense, depth, and other factors peculiar to the individual well. Probably most of the rodless pumping installations anticipate the lifting of oil from depths greater than in any wells yet pumped and temperature at the bottom of the hole is thus an important factor if it affects the operation of the pump. Economy of operation, which includes minimum maintenance combined with effective production results under actual well conditions, is naturally the aim of all.

The new rodless pumper is suitable for pumping effectively 250 bbl. or more of oil per day. It is known as the Smithway Electroil Pumper and has been developed in California by the A. O. Smith Corporation of Milwaukee and Los Angeles. Tests made during the last year have been in wells between 3000 and 5000 ft. Typical performance and power consumption records are indicated by the data given in Table I and the graph shown in Fig. 1.

The pumper is run into the well on the tubing to which it is connected by a goose neck that causes the unit to hang centrally in the hole as shown in Fig. 2. Armored cable containing three conductor wires for transmitting electric current to the unit is clamped to the tubing at 40-ft. intervals and the weight of the cable, the pumper, and the oil-well pump is carried entirely by the tubing string. A reel at the surface, as shown in Fig. 3, accommodates the amount of cable necessary for the deepest expected setting of the pumper and on this the power cable is coiled when the pump is pulled from the hole. The inner end of the cable is connected to an enclosed junction box on the reel with a separate section of the cable running from the reel to a control box. When the cable is connected to the junction at the reel, the latter is locked against turning. The cable is passed into and out of the well over a sheave hung in the derrick above the wellhead.

The control box, as shown in Fig. 4, is mounted at any convenient location beyond the minimum regulated distance from the well. This box contains a properly fused, main 3-phase cut-out switch; an adjustable overload cut-out; an adjustable underload cut-out, and an automatic single-phase protector. A kilowatthour meter is set on a panel provided above the control case.

Briefly, the pumper consists of an electric motor and a hydraulic transmission system to convert the high-speed rotary motion of the motor into a slow reciprocating motion, which is used to drive a conventional oil-well

[1]As of December 31, 1939—Figures from Umpire's office, Los Angeles, California.

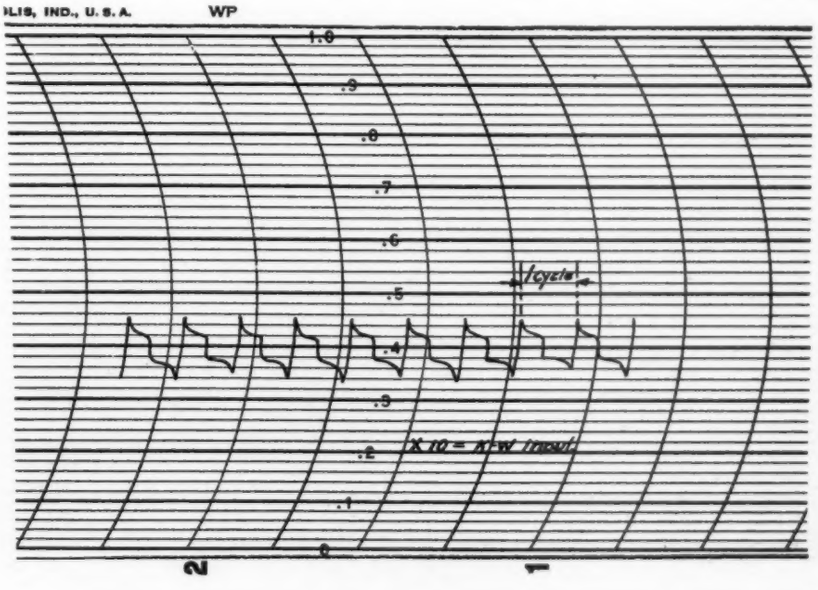

Fig. 1

TABLE I
Performance of typical 100-bbl. per day Electroil pumpers

Unit	Producing time, days	Gross production, bbl.	Percent cut	Power required, kw-hr. per bbl. per 1000 ft. of depth
D	357	43,674	0	0.306
C	217	21,641	34.5	0.362
B	143	14,412	14.0	0.328
A	133	14,980	13.7	0.333

pump. The entire mechanism is enclosed in an outer jacket, the top of which is attached to the tubing production string and the bottom to the oil-well pump. Flow of oil after leaving the pump is upward through the annular space between the outer jacket and the encasement of the pumper mechanism. The passage of the crude oil around the inner assembly keeps the motor and the power oil at approximately the same temperature as that of the crude itself.

The motor is at the top of the unit, as indicated by Fig. 2, and is a 3-phase, induction type operating on a 440-volt a-c. circuit. A 5-hp. motor has been used for pumping as much as 125 bbl. of oil per day from depths of 3000 to 4000 ft. The lower end of the motor shaft is splined for connection to a coupling through which the shaft operating the primary pump is driven. At the top of the motor is a packing for the sealed introduction of the cable. Below the motor is the reservoir for the power oil consisting of lubricating oil of proper viscosity for the operation of the primary pump.

Fig. 2

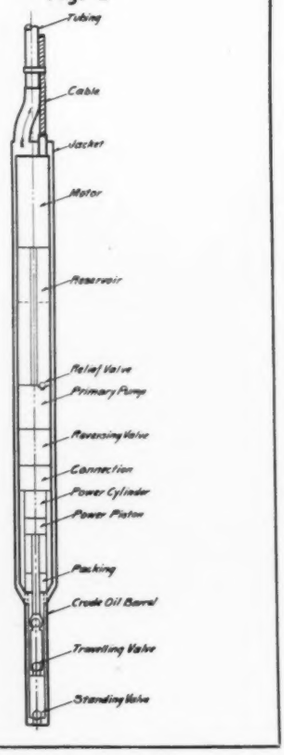

Fig. 3

The primary pump is a screw or viscosity type pump that discharges the power oil at approximately constant volume and builds-up the pressure for operation of the piston actuating the oil-well pump. A pressure-relief safety valve is in the block on which the primary pump is mounted and protects the transmission from excessively high pressures and the motor from overloads. The shaft driving this pump passes through the power oil reservoir into the lower end of which the well pump is screwed.

The vertical reciprocating motion of the lower piston is controlled by a reversing valve of the four-way, distant-control, hydraulic type. Four ports lead from the valve to the cylinder through the head. Two of these carry the main flow of oil to the top and bottom of the cylinder and two small ports are used to effect reversals of the valve piston by hydraulic pressure. The piston is solid with four metallic rings.

The barrel of the oil-well pump is attached to the pumper by means of a special adapter. This pump is one of the simple plunger types and the plunger assembly, in which preferably two traveling valves are used, is connected to the piston rod by means of a floating joint. As the pump operates in connection with the piston rod of

Fig. 4

the pumper, it is, in effect, a pump of the differential type; although suction takes place only on the up-stroke of the plunger, discharge of the crude oil occurs during both strokes. After passing through the upper traveling valve the crude oil enters the space below the piston-rod packing housing and from there through holes into the annulus between the inner assembly and outer jacket of the pumper.

With the reservoir filled with power oil to its proper level, the primary pump forces a constant stream of oil under pressure into the reversing valve. The oil under pressure alternately enters the top and bottom of the cylinder to impart a reciprocating motion to the piston. The piston travel permits a full 36-in. stroke of the well pump plunger. As there is no perceptible stretch in the short piston rod this stroke length is definitely maintained. The speed at which the crude-oil pump is operated is of course determined by well conditions and is controlled by the capacity delivered by the primary pump. The return oil from the cylinder flows through the reversing valve, past the primary pump, and into the reservoir.

Auxiliary equipment needed under various well conditions can be used with the pumper. Gas anchors of any type are attached to the oil-well pump in the usual manner. For sandy wells a blind cage may be screwed directly to the top of the pumper to prevent it being sanded-up when not in operation. When a tubing bleeder is used it is put in the string one or two joints above the pumper. A tubing catcher may also be used as in conventional installations when such a safeguard is desirable.

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Deepening and Completing a Well in the Lisbon Field, Louisiana—A Study in Modern Coöperative Practice

Part 6

By PAUL D. TORREY, Geologist, The Sloan and Zook Company
and
FRANK H. MILLER, Petroleum Engineer
Lisbon Exploration Company, Inc.

PRODUCTION TESTS—Continued

3. Supercompressibility of gas. Supercompressibility is a measure of the deviation of gas from the perfect gas laws. It may be expressed in accordance with the following equation:

$$K = \frac{P_1 V_1 T_2}{P_2 V_2 T_1}$$

in which:

P_1 = elevated pressure in lb. per sq. in. abs.
V_1 = volume at the elevated pressure in cu. ft.
T_2 = temperature at base pressure in deg. Rankine
K = supercompressibility factor
P_2 = base pressure (14.4 lb. per sq. in. abs.)
V_2 = volume at base pressure
T_1 = temperature at elevated pressure in deg. Rankine.

Supercompressibility is a useful factor in determining absolute compressor volumes, orifice meter gas volumes, and gas flow through pipe lines; it is also necessary in test procedure for the determination of the first-stage correction factor, and if available it should be used in the calculation of reserves. In Fig. 16 supercompressibility is plotted against pressure for various temperatures. Lower supercompressibility factors are indicated for lower temperatures, because at higher temperatures, natural gas tends to behave more nearly as a perfect gas. The supercompressibility factors as indicated are for gas separated at the indicated separation pressures and temperatures and not for any one gas. Every point on the curve represents the supercompressibility of gas of different composition. The supercompressibility ratio, "N," for which correction factors are shown in gas metering handbooks, can be derived from the "K" values on the graph as follows:

$$N = \frac{1}{K} - 1$$

and $$F_{pv} = \sqrt{\frac{1}{K}}$$

in which:

N = supercompressibility ratio
K = supercompressibility factor
F_{pv} = correction factor for supercompressibility as used by the American Gas Association.

The "K" values used in this way give absolutely accurate results only when the meter is placed on the vent line from the separator to the flare and when the meter is carrying full separator pressure.

Photographs and biographical sketches of the writers of this article can be found on page 155 of the February issue of *The Petroleum Engineer*, in connection with Part 1.

4. Separated gas gravity. The specific gravity is a necessary factor for the determination of separated gas volumes, both for the test and for full-scale operations. Gravity determinations were made with a Junior Acme Gravity Balance. The barometric pressure was recorded at the time of the gravity determination, and air taken into the balance for "air pressure" readings was first passed through a calcium chloride dryer. At pressures higher than 1300 lb. per sq. in. the formation of retrograde condensate in the balance affected the accuracy of the determinations. In Fig. 17 the specific gravity of the vent gas is plotted versus pressure of separation at three different temperatures.

5. Natural gasoline content of separated gas. The natural gasoline content of the vent gas was determined by charcoal analysis, and is presented graphically in Fig. 18. A fractional analysis of the gas separated at 1100 lb. per sq. in. and 80°F. is given in Table 29.

The absolute gas-oil ratio of the well stream at 1100 lb. per sq. in. and 80°F., the conditions of separation when the sample for fractional analysis was taken, is 50,500 std. cu. ft. per bbl. of condensate at separator pressure. This is equivalent to 0.831 gal. per 1000 std. cu. ft. When the fractional analyses of the gas and liquid are combined in this ratio, the resultant composite analysis of the well stream is as given in Table 30.

From this composition it is seen that the total content of the well stream is 0.767 gal. per M. cu. ft. (18.3 bbl. per million cu. ft.), based on pentanes and heavier, and 1.106 gal. per M. cu. ft. (26.2 bbl. per million cu. ft.), based on butanes and heavier. The natural gasoline content of the vent gas, calculated from the fractional analyses, and based on pentanes and heavier, is 0.283 gal. per M. cu. ft. This value corresponds with the value, 0.220 gal. per M. cu. ft. taken from the curves in Fig. 18.

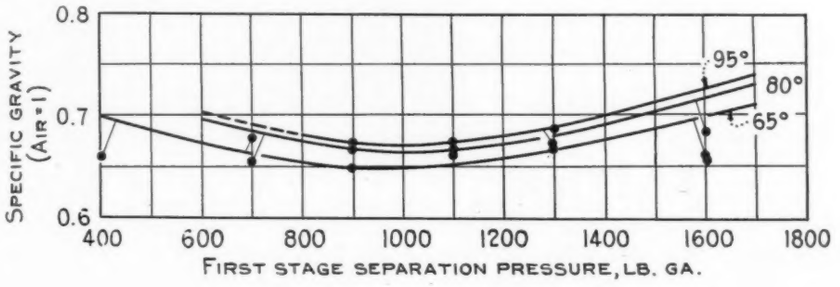
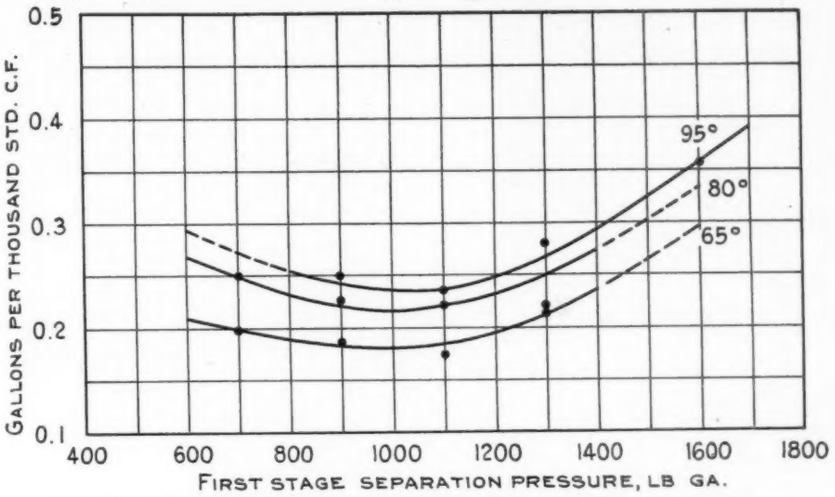


Fig. 17. Specific gravity vs. first-stage pressure

Fig. 18. Condensate yield vs. first-stage pressure



6. Stage separation. Previous work by various investigators indicates that three or four stages of separation is the economic limit to the approach to differential vaporization. Four-stage separation, using three separators and a tank, was chosen for the stage determinations. In connection with these tests it was known that the most efficient intermediate stage pressures can be determined by the following formula:

$$R = \sqrt[n]{\frac{P_1}{P_s}}$$

and

$$P_2 = \frac{P_1}{R} = P_s R^n - 1$$

$$P_3 = \frac{P_1}{R^2} = P_s R^n - 2$$

in which:

$$R = \frac{P_1}{R^2} = \frac{P_2}{P_3} = \frac{P_n}{P_s}$$

N = number of interstages

TABLE 29
Analysis of natural gasoline content of vent gas

Component	Mol. percent
Methane	90.65
Ethane	5.84
Propane	1.83
Isobutane	0.47
n-butane	0.47
Pentanes and heavier	0.74
Total	100.00
Gal. per 1000 cu. ft.—based on butanes and heavier	0.586
Gal. per 1000 cu. ft.—based on pentanes and heavier	0.283
Gal. per 1000 cu. ft.—based on 26-70 natural gasoline	0.444

P_1 = first-stage pressure, lb. per sq. in. abs.

P_2 = second-stage pressure, lb. per sq. in. abs.

P_3 = third-stage pressure, lb. per sq. in. abs.

P_s = storage pressure, lb. per sq. in. abs.

Stage pressures used for stage separation determinations on this test, determined from the above formula are listed in Table 31.

In Fig. 19 the percent recovery, based on accumulated liquid, is shown for four-stage separation. For comparison with the recovery in percent of accumulated liquid, a section of the curves in Fig. 12 is also shown for flash vaporization. The A.P.I. gravity of the residual liquid is also shown, comparing two-stage separation with four-stage separation.

TABLE 30
Composite analysis of hydrocarbon compounds from the well stream

Component	Mol. percent	Gal. per M. cu. ft.
Methane	89.08	
Ethane	5.93	
Propane	1.92	
Isobutane	0.50	0.163
n-butane	0.56	0.176
Pentanes and heavier	2.01	0.767
Total	100.00	1.106

TABLE 31
Stage pressures used for stage separation tests

	Test 1	Test 2	Test 3	Test 4
First-stage pressure, lb. per sq. in.	700	900	1100	1300
Second-stage pressure, lb. per sq. in.	181	215	249	277
Third-stage pressure, lb. per sq. in.	39	43	48	51
Fourth-stage pressure, lb. per sq. in.	0	0	0	0

In Fig. 20 are shown three sets of curves indicating the third- and fourth-stage solution-gas volumes. The total stage-separation solution-gas volumes and the solubility by flash vaporization, a selection of the curves from Fig. 15, are also shown for the sake of comparison. It will be noted that the total gas coming out of solution in four stages of separation is less at all first-stage separation pressures than the solution gas liberated by flash vaporization.

In Fig. 21 the accumulation of unstable condensate in the separator in bbl. per million cu. ft., a section of the curves in Fig. 11; recovery in bbl. per million cu. ft. as a result of flash vaporization, a section of the curves in Fig. 13, and recovery in bbl. per million cu. ft. by stage separation, all for first stage temperatures of 65° and 80°F. are compared. It will be noted that the recovery curves for four-stage separation, a very approximate approach to differential vaporization, are much more similar to flash vaporization curves than they are to the accumulation curves. This can be explained by the presence of methane in the accumulated condensate, which adds to its volume and contributes nothing to the volume of stable condensate.

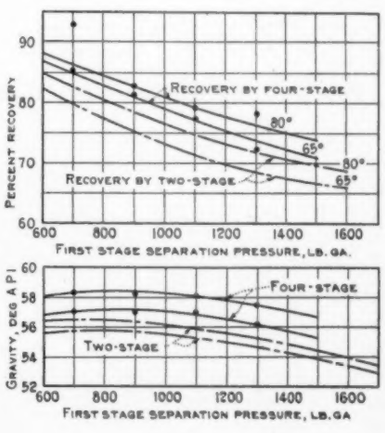
Fig. 22 is a graph showing an Engler distillation on a liquid sample recovered by four-stage separation from the first-stage separator operating at 65°F. and 900 lb. per sq. in.

7. Summary of production tests. A study of the data obtained from the production tests on the Vaughn well leads to the following conclusions:

a. The total stable condensate content of the well stream, recoverable by separation and by a gasoline absorption plant, is approximately 1.10 gal. per M. cu. ft. or 26.2 bbl. per million cu. ft.

b. Maximum accumulation of condensate in the separator has been found to occur at a first-stage operating pres-

Fig. 19. Four-stage recovery compared with two-stage recovery



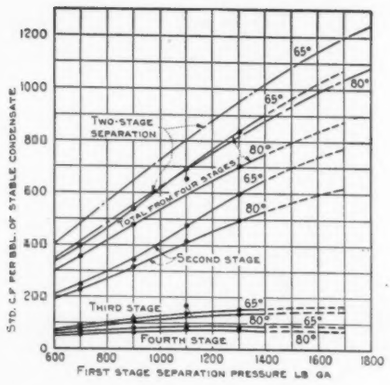


Fig. 20. Third- and fourth-stage recoveries compared with Fig. 15

TABLE 32

Relation of condensate recovery to first-stage pressure for a three-stage separation

First stage pressure, lb. per sq. in.	Recovery of stable condensate, bbl. per MM. cu. ft.
700	16.9
900	16.8
1100	16.3
1300	15.6
1600	14.4

sure of 1250 lb. per sq. in. at a separation temperature of 65°F.

c. Maximum recovery of stable condensate, obtained by flashing the accumulated condensate to atmospheric pressure in one stage, occurs at a first-stage operating pressure of 700 lb. per sq. in. at a separation temperature of 65°F.

d. Maximum recovery of stable condensate obtained by three-stage separation of the accumulated condensate to atmospheric pressure, occurs at a first-stage operating pressure of 800 lb. per sq. in. at a separation temperature of 65°F.

e. The volume of recoverable stable condensate declines as shown in Table 32 at pressures above the optimum point.

8. Bottom-hole pressure. Using a shut-in tubing pressure of 3250 lb. per sq. in. and a specific gravity of gas of 0.70, a bottom-hole pressure of 3985 lb. per sq. in. was calculated in accordance with the formula recommended by the American Gas Association.

9. Physical analysis of reservoir conditions and recommendations for efficient rate of production. Brief mention has been made previously of the most efficient separation pressures that may be used for the recovery of condensate from the Vaughn well. Inasmuch as the primary purpose of attempting to develop deep production in the Lisbon field was to provide high-pressure gas for repressuring the Pettit lime, losses in recovery of condensate certainly will result from repressuring experiments, using gas from a high-stage separator, until measures are taken to install equipment adapted to the maximum extraction of liquid hydrocarbons. This section of the article is devoted to a study of these losses.

a. Loss of natural gasoline. Even when operated under the most efficient separation pressure a total recovery of condensable fractions from the gas produced from the Vaughn well will not be possible without a separate gasoline plant. From the curves shown in Fig. 18, the lowest natural gasoline content of the vent gas in the first stage of separation is at a pressure of about 1000 lb. per sq. in. This figure and the other points on these curves should apply equally well to two-stage separation and to four-stage separation as the gas that may be used for repressuring will be vented gas from the first separator. Using the points established by these curves and extrapolating the latter to a pressure of 2000 lb. per sq. in., the loss of natural gasoline at varying pressures and temperatures is given in Table 33.

The figures presented in Table 33 do not include any propane or normal butane. They do include *iso*butane, pentanes, and heavier hydrocarbons. On the basis of a production of 5,000,000 cu. ft. of gas per day, which the Vaughn well in its present condition is easily capable of making, the actual loss per day of natural gasoline is set forth in Table 34.

The effects of increased temperature on the loss of natural gasoline is best studied in Tables 33 and 34. These losses can only be avoided by the installation of a gasoline plant.

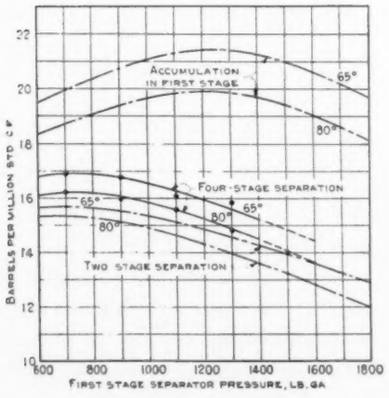


Fig. 21. Comparison of recoveries

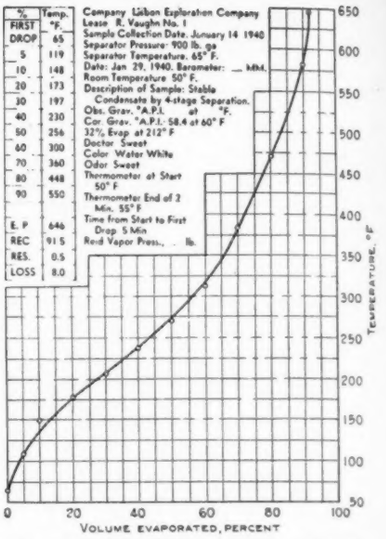


Fig. 22. Distillation curve—900-lb. separator

TABLE 33

Estimated loss of natural gasoline from gas produced from the Vaughn well

First stage separation pressure, lb. per sq. in.	Gasoline loss					
	Gal. per M. cu. ft.			Bbl. per MM. cu. ft.		
	65°F.	80°F.	95°F.	65°F.	80°F.	95°F.
600	0.210	0.270	0.295	5.00	6.43	7.02
800	0.190	0.230	0.255	4.52	5.47	6.07
1000	0.180	0.215	0.235	4.28	5.12	5.59
1200	0.195	0.230	0.250	4.64	5.47	5.95
1400	0.235	0.275	0.295	5.59	6.55	7.02
1600	0.295	0.335	0.355	7.02	7.98	8.45
1800	0.355	0.395	0.425	8.45	9.40	10.11
2000	0.415	0.450	0.495	9.88	10.71	11.79

TABLE 34

Estimated loss of natural gasoline from the Vaughn well on the basis of a production of 5,000,000 cu. ft. per day

First stage separation pressure, lb. per sq. in.	Loss, bbl. per day		
	65° F.	80° F.	95° F.
600	25.00	32.15	35.10
800	22.60	27.35	30.35
1000	21.40	25.60	27.95
1200	23.20	27.35	29.75
1400	27.95	32.75	35.10
1600	35.10	39.90	42.25
1800	42.25	47.00	50.55
2000	49.40	53.55	58.95

EDITOR'S NOTE: This article will be concluded in a forthcoming issue.

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Use of Bulk Cement in Wells

PETROLEUM ENGINEER EXCLUSIVE FEATURE

Large capacity cement hoppers reduce time required to mix and place slurry in deep wells

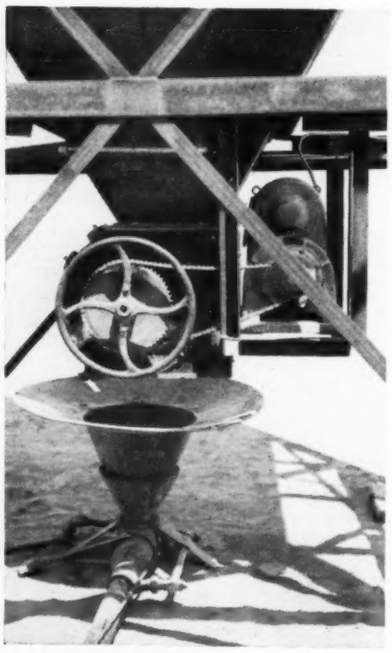
ALTHOUGH bulk cement has been used for some time in other oil-producing areas, only recently was the practice introduced in the California fields. One reason has probably been that the quantity of cement used in many cases is rather large, as most of the deep wells have long water strings of casing cemented with 2000 to 2500 sacks of cement. Provision for handling that amount of cement rapidly has created a problem.

Equipment for handling cement in bulk has been developed by a company supplying cement in the San Joaquin Valley. The bulk cement hoppers or tanks are transported to the field on a truck and then set up at the well. These hoppers hold 1000 sacks of cement each and when the job requires large quantities of cement, two hoppers are placed at the well. Cement is loaded into the hoppers by means of a conveyor. The equipment is all portable but in fields being rapidly developed the bulk cement hoppers are usually left in the field and transported from well to well as needed.

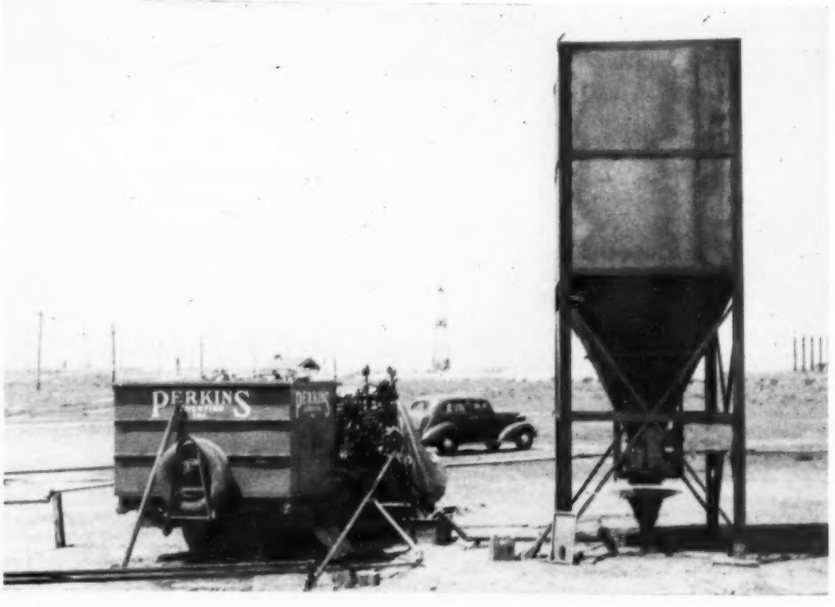
The original design of the hoppers provided for feeding the cement by pneumatic means to the opening at the bottom. It has been found, however, that this was not necessary and gravity flow of the dry cement is now employed. As the cement leaves the bottom of the tank it passes through a meter that measures the volume. The rate of discharge is controlled and facilitates maintenance of the desired consistency of the slurry mix.

In addition to the advantages offered by metering the cement and controlling the mix, the use of bulk cement eliminates cement dust, which is often harmful as well as disagreeable, especially in a wind. The cement falls directly into the funnel, as indicated by the illustration, and goes from there to the cementing truck. Many of the cementing jobs in California are two-truck jobs but the procedure followed in the cementing operation is the same with bulk cement as when sacked cement is used.

One of the cementing companies has just erected a bulk cement plant north of Bakersfield but will use a somewhat different system for handling the bulk jobs. At this plant there is a battery of 1000-sack bulk cement hoppers. The cement is here loaded into bulk cement trucks and transported to the field in these trucks from which it is taken for mixing with water in the usual manner. As the capacity of the bulk cement truck is much smaller than a hopper, it will, of course, be necessary to use a number of trucks for jobs requiring large quantities of cement.



The amount of cement issuing from the bottom of the hopper is both controlled and measured by a motor-operated "meter"



Bulk cement from the large hopper is fed at any desired rate to the mixing truck

P 501.72
P 214.

The Behavior of Oil and Gas Under High Pressures and Temperatures

Part 2 (Concluded)

By HARVEY T. KENNEDY

Gulf Research and Development Company

THE failure of Raoult's or Dalton's laws at a given pressure does not necessarily mean that the charts are not of general validity at that pressure. It is known, however, that critical pressures vary greatly with the composition of hydrocarbon mixtures, and as the equilibrium constant must become unity for each component at the critical pressure, it is seen that the portion of the diagram on the right must be drawn in reference to a mixture of definite composition. Thus, Fig. 9 shows critical pressures, some measured and some extrapolated, for two component mixtures, after Sage, Hicks, and Lacey (in a paper delivered at the Eighth Mid-Year Meeting of the A.P.I., Wichita, Kansas, May, 1938). It is seen that, in general, hydrocarbons widely different in volatility have high critical pressures, and hydrocarbons close together have low critical pressures. The analogy should be noted between this behavior and the law of solubility, which states that mutual solubility of chemically similar materials is high, and dissimilar materials low.

Hydrocarbon mixtures comprising natural gas, and particularly those occurring in petroleum, are extremely complex. Although a great amount of work has been done, mostly under the auspices of the American Petroleum Institute, not a single crude oil has been completely analyzed. It is not surprising, therefore, that equilibrium data based on composition in terms of methane, ethane, and higher homologues should be of limited value. Every analysis must end with such a term "hexane plus" or "heptane plus," representing the extent of our analytical ability and tacitly assuming that the composition of the remainder is immaterial. Such an assumption is entirely unwarranted when dealing with hydrocarbons that may exist in either the vapor or liquid phase. If they exist only in the liquid phase, as at lower pressures, a measurement of the molecular weight of the liquid may suffice to describe it adequately. In our experimental work on formation equilibria, therefore, we deal with gas and oil as obtained from the reservoir, and reunite them in the same ratio, without concern for the analyses in terms of their ultimate constituents. As we cannot express the composition in chemical terms, our findings are limited in applicability to a definite reservoir. On the other hand, our accuracy is increased to a point where it can be used with the confidence that it represents the actual conditions in the reservoir.

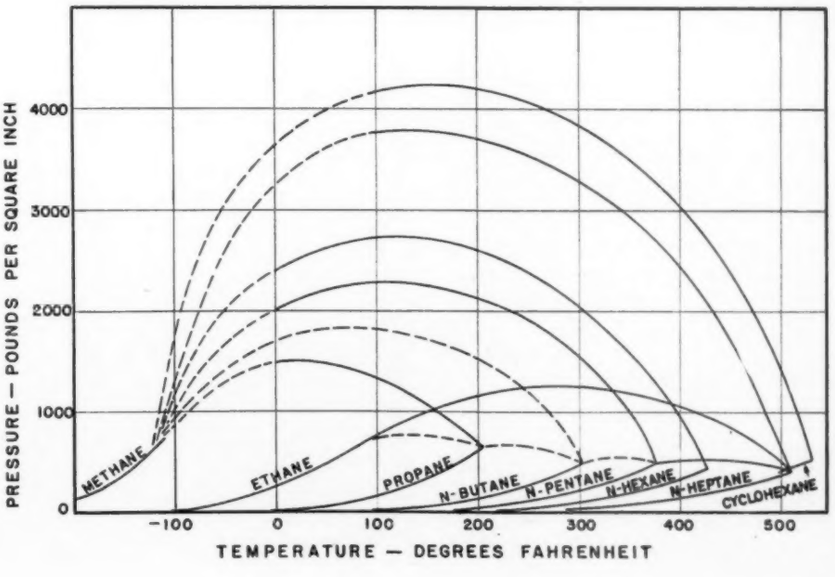
A photograph and biographical sketch of the writer of this article can be found on Page 117 of the June issue of *The Petroleum Engineer*, in connection with Part 1.

Fig. 10 shows a glass pressure tube employed to investigate equilibrium between gas and oil. The oil is measured into the tube and a measured volume of gas is introduced into it by mercury displacement. It is mounted as shown in Fig. 11, and pressure is applied by connecting the left arm of the apparatus with a high-pressure oil pump. Stirring is obtained by the reciprocating action of the electro magnet on a tiny steel ball inside the tube. Temperature is controlled by immersing the tube in an oil bath, as shown in Fig. 12. Measurements of volume are made by means of a cathetometer reading to 0.001 mm. The general arrangement of the apparatus, including the dead-weight tester for pressure measurement, is shown in Fig. 13.

Information of value from several standpoints can be obtained from examining high-pressure oil-gas equilibria. If a mixture is saturated with regard to oil of normal characteristics at formation temperature and pressure, it is probable, although not certain, that oil exists in lower parts of the structure. If a high-pressure gas, capable of dissolving large amounts of oil, contains little or no oil, we can be quite certain that it is not in contact with oil in the reservoir, and that drilling deeper or on the flanks of the structure, if continuous, will not pay out in oil.

A second contribution that work of this kind can make lies in determining

Fig. 9. Critical pressures for binary mixtures *(after Sage, Hicks, and Lacey)*



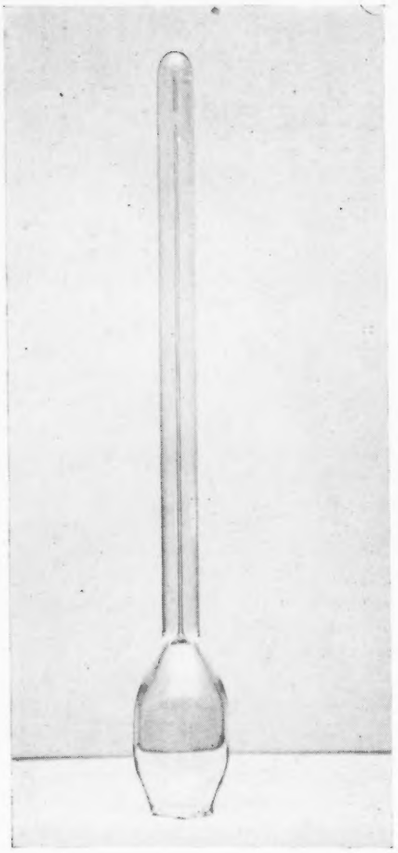


Fig. 10. Glass pressure tube used to investigate oil-gas equilibrium

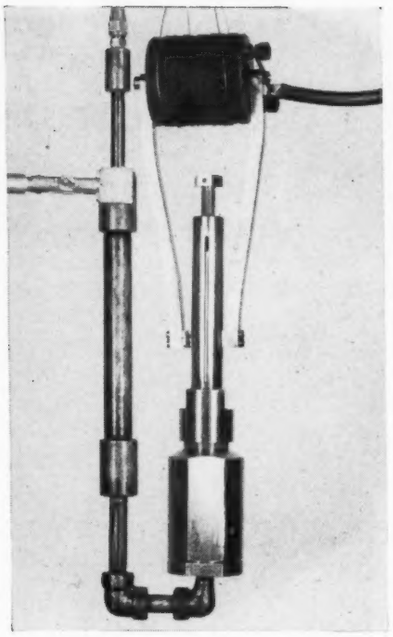


Fig. 11. Manner of mounting glass pressure tube shown in Fig. 10

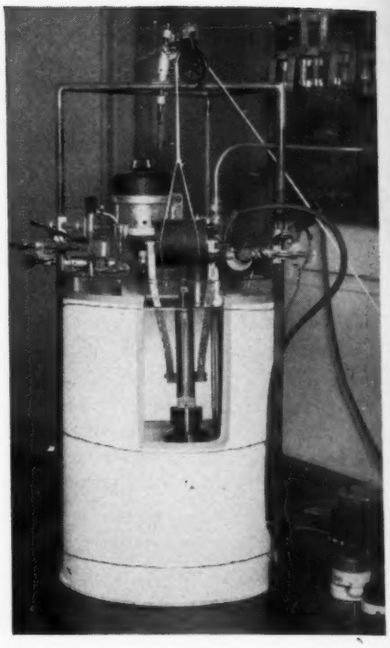


Fig. 12. Temperature is controlled by immersing glass pressure tube in an oil bath

the proper method of production. Fig. 14 shows the dew-point and oil and gas volumes for a well in the Fox field, Oklahoma. The dew-point is 3255 lb. at the reservoir temperature, which indicates that above this pressure, the fluid produced by the well consists of a single phase. At the dew-point pressure, as the single phase system is expanded, liquid condenses and increases in amount as shown by the liquid volume curve, reaching a maximum volume at 1750 lb., and thereafter decreases, due to vaporization over this pressure range. Fig. 15 shows similar measurements on a well in Moore's field, Texas, where a dew-point of 3050 lb. per sq. in. was found.

In the reservoir, condensation occurs just as in the high-pressure tubes in the laboratory, if the reservoir pressure is allowed to decline to less than the dew-point of the mixture, and the oil so condensed clings to the rock instead of accompanying the gas to the surface, and thus becomes forever irrecoverable. Fig. 16 shows data of Dr. Patten *(Oil Weekly 92*, p. 20, Dec. 12, 1938) of the Texas Railroad Commission on the LaBlanca field, Texas.

The chart shows the measured gas-oil ratio during a drop in reservoir pressure from 3800 to 2200 lb.; accompanying this pressure drop, the condensate content has dropped from 9 bbl. to 2.6 bbl. per million cu. ft. of gas, and a corresponding increase in gas-condensate ratio has occurred. Extrapolating these data to zero pressure by means of laboratory measurements, Dr. Patten shows that 65 percent of the liquid content of the gas at a pressure of 3800 lb. will condense

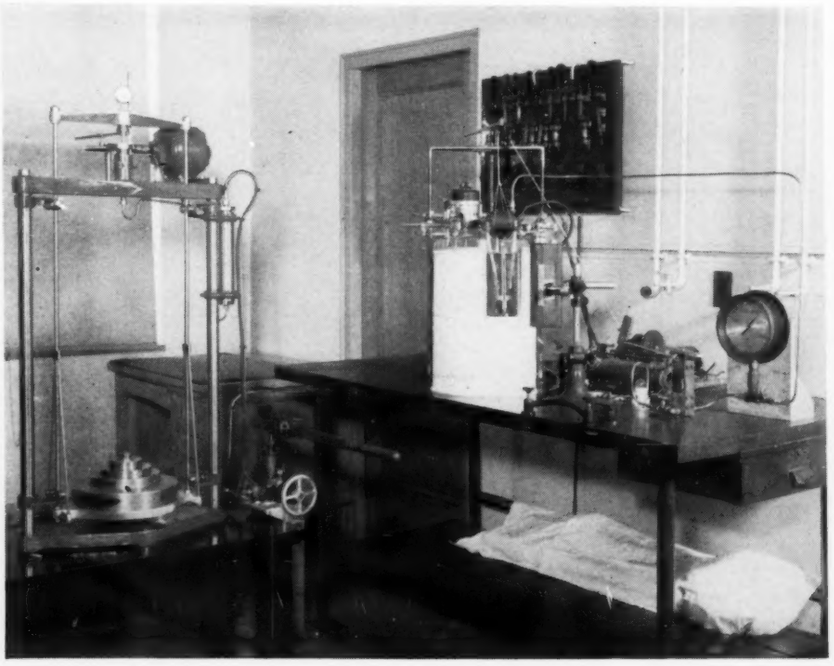


Fig. 13. Arrangement of equipment for measuring oil-gas equilibrium

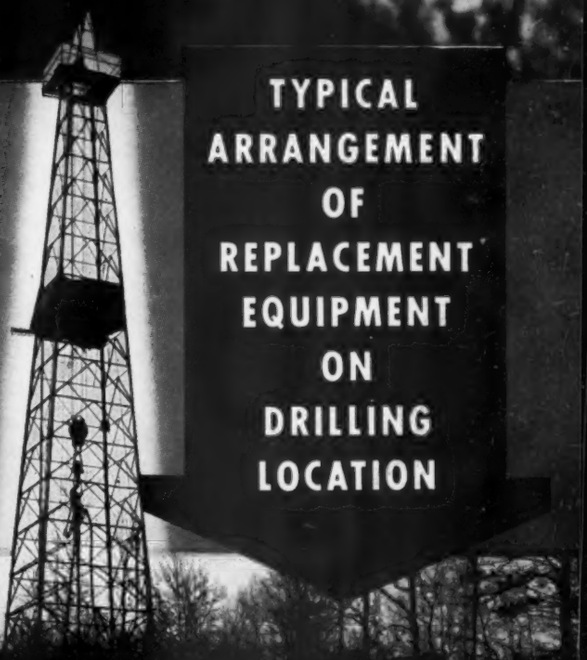
(The sample tube containing oil and gas is placed in the steel armor, the poles of the magnet inserted in the slots in the armor, and the magnet is raised and lowered by a motor-driven eccentric shown on the bench against the wall. A 1/64-in. steel ball moves with the magnet and provides stirring for the sample. Rheostats are available to regulate the heating current and to adjust the magnetic flux, which raises and lowers the ball. Variations within the sample tube are observed through the cathetometer mounted on the stand. The sensitive deadweight tester is shown at the left.)

NATIONAL SHRINK THREAD TOOL JOINTS

REPLACED AT THE RIG

Advantages OF REPLACEMENTS AT RIG

- **EASE OF RENEWAL—** Simple equipment set up at rig. No bucking-on machine required. Application made by hand.
- **REDUCTION OF "RIG DOWN" TIME—** Complete tool joint re-application on full string can be made while rig is in operation.
- **REMOVAL OF TOOL JOINT WITHOUT PIPE THREAD DAMAGE—** No re-threading of pipe. No re-chasing of pipe threads.
- **ELIMINATION OF HEAVY TRUCKING EXPENSE—** Replacement done at Well.
- **REPLACEMENT EXPENSE—** Nominal.
- **ALL OPERATIONS DEPENDABLY SUPERVISED.**



TYPICAL ARRANGEMENT OF REPLACEMENT EQUIPMENT ON DRILLING LOCATION

PORTABLE FURNACE, HAND TOOLS AND ACCESSORIES, WITH TENT SHELTER

DOMESTIC

EXECUTIVE OFFICES
PITTSBURGH, PENNA.

GENERAL SALES OFFICE
TOLEDO, OHIO

DIVISION OFFICES
FT. WORTH, TEX. • TULSA, OKLA.
TORRANCE, CALIF.

THE NATIONAL SUPPLY COMPANY

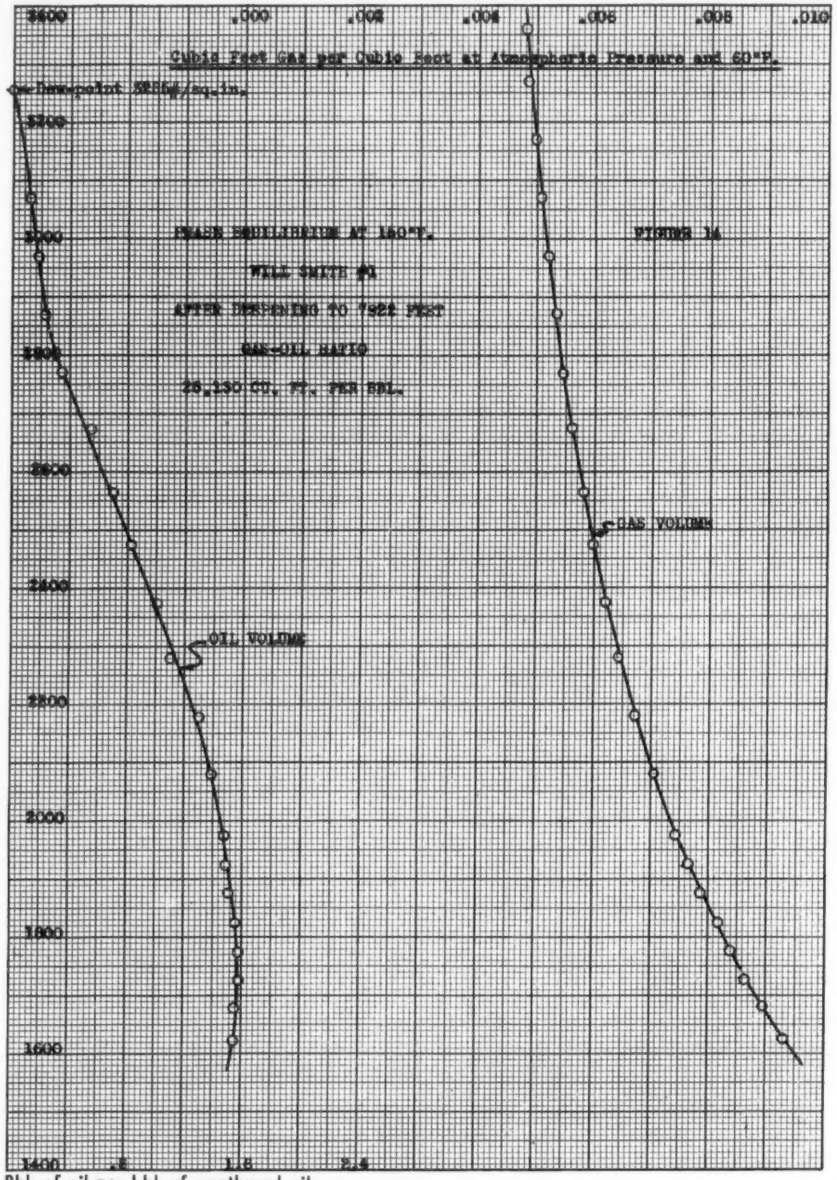
EXPORT

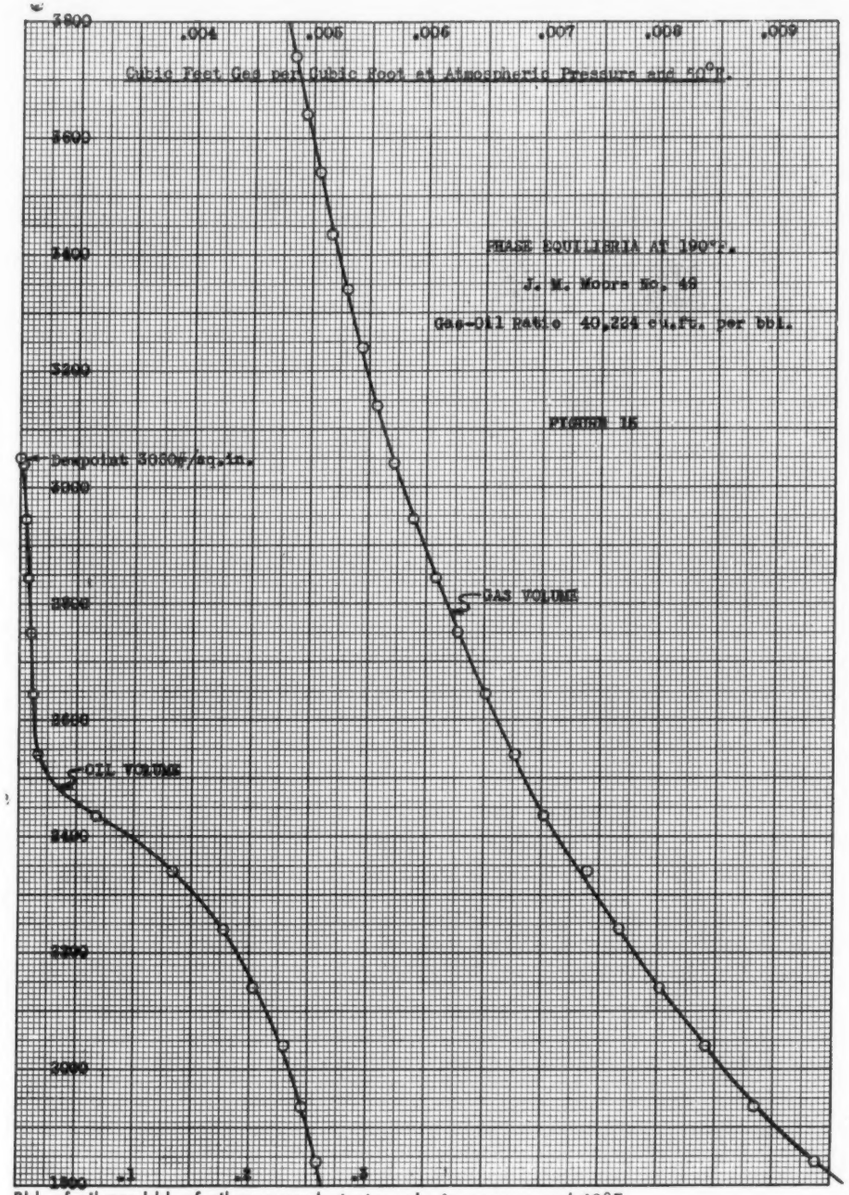
THE NATIONAL SUPPLY CORPORATION
30 ROCKEFELLER PLAZA
NEW YORK, N.Y. U.S.A.

RIVER PLATE HOUSE
12 10 PLACE, LONDON, E.C. 2
LIMITED LIABILITY

PLOESTI, ROUMANIA

MARACAIBO, VENEZUELA


Cubic Feet Gas per Cubic Foot at Atmospheric Pressure and 60°F.
PHASE EQUILIBRIUM AT 160°F.
FIGURE 14
WELL SMITH #3
AFTER DEEPENING TO 7924 FEET
GAS-OIL RATIO
26,150 CU. FT. PER BBL.
GAS VOLUME
OIL VOLUME
Bbl. of oil per bbl. of weathered oil


Cubic Feet Gas per Cubic Foot at Atmospheric Pressure and 60°F.
PHASE EQUILIBRIA AT 190°F.
J. M. Moore No. 48
Gas-Oil Ratio 40,224 cu.Ft. per bbl.
FIGURE 15
GAS VOLUME
OIL VOLUME
Bbl. of oil per bbl. of oil recovered at atmospheric pressure and 60°F

Figs. 14 and 15. Representative analyses of phase equilibria

and become forever non-recoverable if the present production practice is followed. The original reservoir pressure was 4200 lb. and had a condensate content of 18 bbl. per million cu. ft. On this basis, it is shown that 82 percent of the condensate will be in the reservoir when the last well is plugged and abandoned, unless some pressure-maintenance system is adopted. The impossibility of recovery, once a condensate has formed within the reservoir, is evident when one considers that, if all the condensate were left in the reservoir, stripped of its gas, it would occupy only 3 or 4 percent of the reservoir volume. No method of production is known by which oil in such small saturations, tightly held by capillarity, can be recovered.

In most condensate reservoirs the percentage loss due to pressure decline is even higher, because of the higher condensate content per million cu. ft., and the sharpness of the decrease in condensate content as the pressure declines.

In order to maintain pressure as fluid is produced from a reservoir, the volume originally occupied by the fluid must obviously be filled with another material. In some cases, there is no commercial method by which the pressure can be maintained, and the loss of distillate may be considered as a necessary evil, as is the unrecovered portion of oil left in oil sands in shallow production. In other cases, the losses can be eliminated almost entirely.

Most reservoirs have a natural water drive, and if fluid is not withdrawn too rapidly, the pressure will not decline appreciably as production proceeds. In this type, the condensate losses mentioned above can be eliminated by wide well spacing and low production rates from each well. In other fields, artificial water flooding may be feasible if applied when the structure is first drilled. Water flooding after the gas is depleted will be of no avail, as many investigators have checked the conclusion that water will not recover the last traces of oil.

Repressuring with gas after the pressure has once declined materially is probably impracticable, because gas in sufficient volume would not ordinarily be available and secondly, because little could be expected in the way of economic returns until a very high reservoir pressure had been reached, as solubility of the oil in the gas, rather than ordinary gas drive, would have to be depended on, and this effect is exhibited appreciably only at high pressures.

One objection to the application of ordinary water flooding or repressuring operations to condensate fields is the expense necessarily involved in drilling deep wells for this purpose, if non-productive edge wells are not available. This objection may be overcome, in large measure, if the reservoir is of substantial thickness, and if packers may be set in producing wells to allow production from above, while excess gas is injected below the packer. In other wells, production is obtained from below the same structural level while injection takes place above it. To reduce underground mixing, it would be necessary to segregate wells producing from the same side of the packer in one part of the field. In this manner the total fluid taken from the reservoir when all the condensate has been theoretically exhausted would amount to the small volume used for power production plus the volume occupied by the condensate in solution, the latter normally amounting to 2 to 4 percent of the reservoir volume. As shown in Figs. 14 and 15, it is unnecessary to expand the gas to less than about 2000 lb. per sq. in. to obtain the maximum yield of oil. Recompression from this pressure to original reservoir pressures, say 4000 lb., would require substantially the same power as to compress the same mass of gas from one atmosphere to two atmospheres and would not require excessive volumes of gas for fuel.

Fig. 17, also taken from Patten, shows the variation of A.P.I. gravity of the condensate as the pressure is lowered. The initial increase in gravity reflects the condensing-out of more soluble lighter hydrocarbons as compared to the initial formation of volatile heavy ends, and the subsequent decrease in gravity shows the loss of volatile hydrocarbons originally dissolved in the oil.

A third application of equilibrium measurements at high pressures deals with the investigation of efficient methods of separating oil and gas, after they have reached the surface. This work is at present undergoing considerable study and may be the subject of a later article. It should be noted in this connection that until very recently, no correct data have been available as a basis for choice of separator pressures for condensate wells.

This discussion of equilibrium between oil and gas at high temperatures and pressures has touched only a few of the more important of many applications of this information. By the data already obtained, or by the methods presented, every property of gas and oil mixtures can be followed from the reservoir to the stock tank and gas line, and we can consider ourselves ready for the problems that arise from deeper, hotter, and higher-pressure wells.

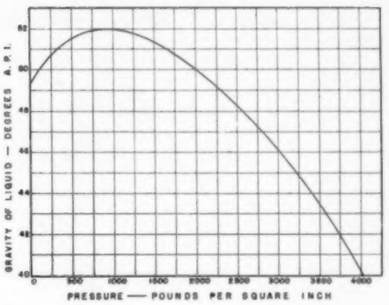
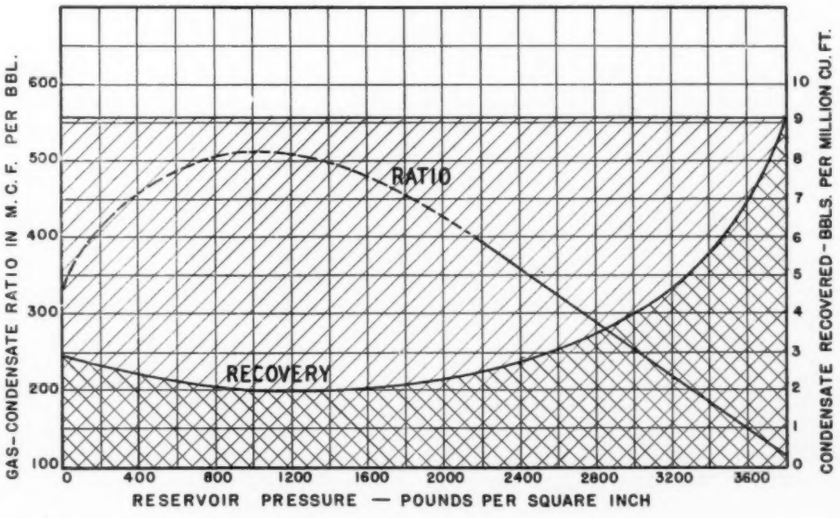


Fig. 17. Gravity vs. pressure for a condensate well at reservoir temperature ***(after Patten and Ivey)***

Fig. 16. Reservoir pressure—composition curves, La Blanca field, Texas ***(after Patten and Ivey)***



Running Tour
WITH MEN IN THE INDUSTRY

DR. RALPH F. NIELSON has joined the staff of the research group that is investigating the secondary recovery of petroleum by water flooding at the Mineral Industries Experiment Station of The Pennsylvania State College. Previously he was research engineer with the Stanolind Oil and Gas Company at Tulsa, Oklahoma, specializing in studies of the equilibrium between liquid and gaseous hydrocarbons and the role of surface forces in oil production.

D. J. McNEIL, Tulsa, Oklahoma, has resigned as district geologist of the Shell Oil Company, Inc., to become senior geologist for McColl-Frontenac Oil Company, a subsidiary of The Texas Company. He will have his headquarters at Calgary, Alberta, Canada. His post in the Oklahoma district will be taken over by **G. B. HARDISON,** district geologist at Wichita Falls, Texas.

H. T. GALEY, manager of the London, England, office of the Gulf Exploration Company; **T. H. WALLACE,** in charge of drilling; **J. C. DUGAS, H. H. GILBREATH,** and **M. J. SPARKS, JR.,** drillers, recently returned to the United States from England.

J. C. POOLE, district geologist at Corpus Christi, Texas, for the Barnsdall Oil Company, has resigned and opened consulting offices in Corpus Christi.

C. A. HILL, Dallas, Texas, has been made superintendent of the Wewoka, Oklahoma, district by the Magnolia Petroleum Company. The district has been enlarged to include the major part of the Greater Seminole field. He succeeds **O. H. STOUT,** who has been transferred to Lovington, New Mexico.

CLARENCE GRAHAM has been appointed superintendent of the Bradford district, Pennsylvania, for the South Penn Oil Company. He has been superintendent of the Oil City district. The latter post is being taken over by **B. H. SPENCE,** formerly field foreman at Pleasantville, Pennsylvania.

DICK WHITE, geologist for the Standard Oil Company of Texas, has been transferred from the Houston to the Midland, Texas, office, where he will be in charge of geological work in West Texas and southeast New Mexico. He succeeds **JOHN EMERY ADAMS,** who is opening an office in New Orleans, Louisiana, to supervise the company's geological operations in the southern states.

C. E. CRAWLEY has retired as an executive of the Consolidated Oil Corporation. He had been associated with Consolidated and predecessor companies for 20 years. For several years he had been in charge of production and pipe-line operations of the company's subsidiaries.

C. R. MINOR, vice-president of Gulf Refining Company in charge of the Shreveport, Louisiana, division, retired July 1. He had been with the company since 1904 and had been in charge of the Shreveport division since 1918. **J. T. GOODMAN** succeeds him. His title will be that of general war.

GEORGE H. EDGERTON, Rio Grande City, Texas; **BRUCE S. WEAVER,** Donna, Texas, and **J. J. SANDERS,** Corpus Christi, Texas, have joined the engineering staff of the Texas Railroad Commission at Corpus Christi.

DR. ROBERT J. WATSON, geologist and geophysicist for the Carter Oil Company, Tulsa, Oklahoma, has returned home after a brief stay in Cairo, Egypt. Dr. Watson's assignment to Africa was interrupted by the agent.

A. L. HENDERSON, production superintendent for West Texas and New Mexico for the Ohio Oil Company, has been transferred to Midland, from Iraan, Texas. **W. C. KINKEL,** district geologist; **HUGH STOREY** and **W. G. CLARKSON,** of the geological staff, and **CHARLES A. HITT,** district land man, have been transferred from San Angelo, Texas, to Midland. These changes were brought about by a consolidation of the West Texas division of the company.

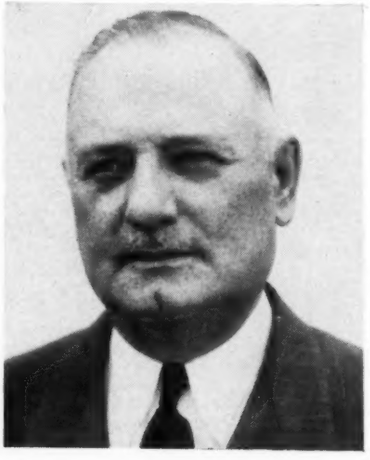
LEE FRIEDMAN and **JOE WEILER** have been added to the engineering staff of the Texas Railroad Commission at the Gulf Coast Division offices, Houston, Texas.

HARRY T. SMITH, traffic manager of Worthington Pump and Machinery Corporation, died at his home on July 3, 1940. Smith was associated with Worthington for 54 years, having started with the old Henry R. Worthington Hydraulic Works, then in Brooklyn.

Smith was a native of Brooklyn, and was educated in its Public Schools and at Pratt Institute. At the time of his death, he was a resident of Metuchen, New Jersey, and his Worthington headquarters have been, since 1933, at Harrison, New Jersey.

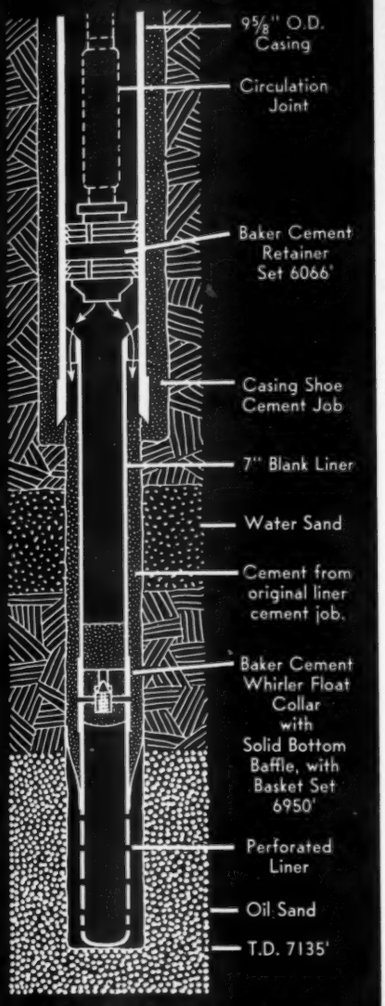
Popular with his associates, and admired for his ability, his passing is a great loss to all who knew him.

W. S. PROCTOR has been appointed factory representative in California by Oil Center Tool Company, Houston, Texas. For 14 years prior



W. S. PROCTOR

to joining Oil Center Tool Company, Proctor was engaged in oil-field equipment sales work in the Gulf Coast and Mid-Continent areas. He has established residence and offices in Santa Ana, California.


9⅝" O.D. Casing
Circulation Joint
Baker Cement Retainer Set 6066'
Casing Shoe Cement Job
7" Blank Liner
Water Sand
Cement from original liner cement job.
Baker Cement Whirler Float Collar with Solid Bottom Baffle, with Basket Set 6950'
Perforated Liner
Oil Sand
T.D. 7135'

Performing Squeeze Job with Baker Cement Retainer to Re-cement Imperfect Liner Splice

BAKER CEMENT RETAINER

CASE STUDY NO. 405

Problem: *To Rectify a Wet Liner Splice.*

Method: *Set Cement Retainer above Splice and Perform Squeeze Cement Job.*

Result: *100% Successful . . . Liner Splice Tested Dry.*

• DETAILS •

Field: Montebello, Calif.

Depth of Well: 7135'

Depth Retainer Set: 6066'

Breakdown Pressure: 2000#

Final Pressure: 2400#

Number of Sax Mixed: 60

Number of Sax Put Away: 60

How Cement Discharged: through Retainer & around Liner Splice

5

A Case study of an Actual Well Repair Problem Solved By Using the Baker Cement Retainer

BAKER ★ SAVE A WELL ★ CEMENT RETAINER

"For Friendly Service, and Dependable Products, Specify BAKER."

THE BAKER CEMENT RETAINER . . .

has provided the solution to many Cementing, Well Repair, and Well Completion problems confronting the modern operator . . . Perhaps it will solve a particular problem confronting YOU. Complete details concerning its many practical field applications will be found in the Baker Section of the Composite Catalog . . . also in Baker Broadcast No. 17-A, a comprehensive, 40-page illustrated treatise which will be sent to interested oil men upon request.

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Squeeze Jobs • Recementing • Cementing Behind Sections of Pipe • Reducing Gas/Oil Ratios • Series Cementing • Plugging off Bottom Fluids • Plugging back to Upper Zones • Testing Upper Cased Formations • As a Heaving Plug • As a Bridge Plug at any Place in Casing or Liner • Open Hole Acidizing • Open Hole Squeeze Cementing

BAKER CEMENT RETAINER

MACHINERY and EQUIPMENT

Improved Combination Hook

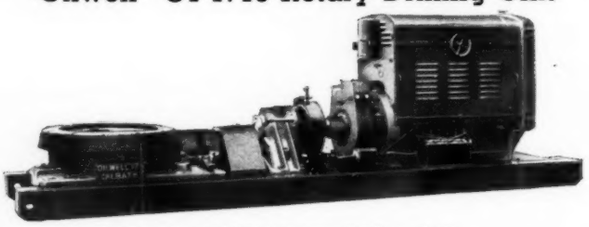
AN improved combination hook is announced by Regan Forge and Engineering Company. It is available for 300-ton capacity and can also be ordered for 100- and 200-ton capacities. This hook embodies two separate load-carrying elements. The large lower hook carries the swivel bail and the two smaller hook elements formed by the cross yoke carry the elevator links. The cross yoke is slidably mounted within an aperture of the main hook. This hook can be locked in any of four positions. It has a safety lock. When the latch on the large lower hook is in open position it hangs at a convenient angle and readily engages the swivel bail, the weight of which automatically closes and locks the latch. This hook is cast of alloy steel, heat-treated to produce maximum physical properties, and is tested to one and one-half times the rated safe load. The overall height of the 300-ton hook is 120 in. Full details may be obtained by addressing Regan Forge and Engineering Company, P. O. Box 150, San Pedro, California.

Toledo Simpact Self-Contained Ratchet Threader

THE Toledo Pipe Threading Machine Company, Toledo, Ohio, manufacturers of the well-known line of "Toledo" pipe tools and power pipe machines, announces the new "Toledo" Simpact self-contained 1-in. to 2-in. ratchet threader. Officials of the company state that this new tool cuts perfectly tapered threads with little effort. The tool uses high-speed steel dies. These are quickly changed from one size to another simply by pushing the size selector buttons and slipping the dies in the proper steps. It saves approximately half the time usually required for changing sizes, it is stated. The dies are backed by tapered steps so that smooth, long tapered threads are always assured, according to the manufacturer. A 3-jaw rear gripping device is employed. It is equipped with three broad-faced chuck jaws, graduated guide posts, and large wing-head thumb screws, which assure easy, positive, accurate centering of the tool on the pipe, it is stated. The 24-in. tubular steel handle is strong and light, and the tool is light in weight, yet no light weight die castings are used in its construction. The dies are deep throated and may be resharpened many times.

The Toledo Pipe Threading Machine Company advises that this new tool was placed on the market July 1 and is being sold through all leading supply distributors throughout the country.

"Oilwell" CT-1715 Rotary Drilling Unit



"Oilwell" CT-1715 Rotary Drilling Unit

A ROTARY drilling unit with internal-combustion engine prime mover was exhibited for the first time at the recent International Petroleum Exposition by the Oil Well Supply Company, Dallas, Texas. Several identical units are operating in Illinois and other active areas.

This unit is a compact and portable assembly on steel skids, providing individual, direct drive from either a 150-hp. or 200-hp. engine through a hydraulic torque converter and geared speed increaser to a modern, high-speed, oilbath rotary. Smooth and flexible power-flow like that of a steam engine, together with wide range of power and speed, is accomplished through the use of the hydraulic torque converter. The hydraulic drive cushions the shocks that are inherent in rapidly turning a long string of drill pipe in torsion, thus contributing not only to the life of the moving parts of the rotary and prime mover, but to the drill pipe and bit as well.

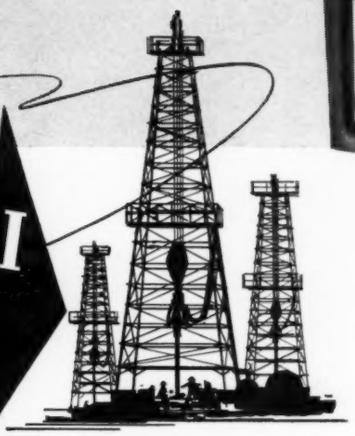
Whether the drilling requirement calls for slow table speeds as in coring operations, or high table speeds ranging between 250 and 300 r.p.m., the drive responds through simply changing the engine throttle setting. There are no other controls or clutches. If a bit or reamer sticks while the engine is operating with a normal, fixed throttle setting, the output torque requirement reaches a point greater than the torque input, with the result that there is no further wind-up of the drill pipe. To unwind the pipe and free the bit or reamer, it is merely necessary to close the engine throttle to the idling position.

An unusual feature of this rotary drilling unit is the vacuum brake that absorbs the slight drag of the converter fluid when the engine is idling and thus prevents the table from turning when rotation is not desired.

This new rotary drilling unit gives to the rotary drive of an internal-combustion rig the advantages for which the rotary drilling unit equipped with a steam engine is so well known, the manufacturer asserts. It also increases the capacity of a compound-engine rig by releasing both engines for slush pump drive without connection to the rotary.

PROMOTE PRODUCTION EFFICIENCY

With these JARECKI Specialties



"Erie" Stuffing Box

"Erie" Improved Stuffing Box. Of heavy malleable iron. Two glands, each 2½" long, provide a bearing area which increases life of both glands and rod. Oil reservoir at top lubricates rod when well pumps off.

Threadless Bell Nipple

JARECKI Threadless Hinged Bell Nipple. An improved sucker rod guide which protects the threads of the pumping tee when running or pulling rods, and provides a level seat for the elevators. Clamps around the band of any standard malleable tee of corresponding size.

Jarecki Pumping Tee

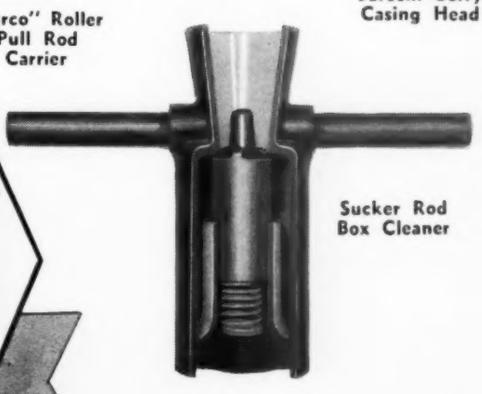
JARECKI Improved Pumping Tee. Is threaded to screw directly onto either regular or upset-thread tubing, thus eliminates swaged nipples, sub-nipples and bushings. Made of heavy malleable iron, it has three times the weight and strength of conventional tees.

"Jarco" Roller Pull Rod Carrier

"Jarco" Roller Pull Rod Carrier. Special lubricating method meters oil from reservoir through a porous bronze bushing, and one filling of oil lasts a year, for heavy duty carrier shown—6 months for regular carrier.

Jarecki Berry Casing Head

JARECKI Improved Berry Casing Head. Of semi-steel for high pressures. Has full-length A. P. I. casing thread and full-length side-outlet threads; inclined set screws arranged perpendicular to bevelled edge of top; circular interior; set screw flange provided with drain holes.



Sucker Rod Box Cleaner

JARECKI-COLLINS Sucker-Rod Box Cleaner. Removes dirt, sand and gritty material from sucker rod boxes and couplings by automatically jetting a cleaning fluid against the threads. Reduces pin breaks.

Descriptive bulletins on request.

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General Offices: St. Louis, Mo. Home Office and Factory: Erie, Pa., U. S. A.
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Branch Stores at All Important Places in the Oil Country.

Model 12A Buckeye Trencher Announced

THE Buckeye Traction Ditcher Company, Findlay, Ohio, has announced an addition to its line of rotary wheel type and boom type trenchers. A wheel type and designated as Model 12A, the new trencher incorporates many new features in a single, rugged, compact unit.

The excavator wheel frame is of a new "trussed bridge" construction, which provides greater strength and resistance to distortion than former designs of equal weight, the manufacturer states.

A "fluid coupling," which is optional equipment, positively protects transmissions from sudden shocks and prevents engine stalling, it is further asserted.

The conveyor belt has new type belt guide clips, developed by Buckeye, which insure even tracking of belt, at the same time minimizing belt and pulley wear.

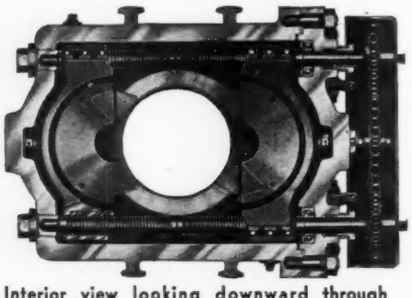
The excavator final drive is the Buckeye Constant Center Type, which eliminates the need for idlers to take-up the chain slack and provides a smooth flow of power at any digging depth of excavator wheel, according to the maker.

The new Model 12A cuts trench to 26 in. wide and to 5 ft. 6 in. deep. Overall width (exclusive of spoil conveyor) is only 6 ft. 8 in.; overall digging height is 8 ft. 1¼ in. A wide range of cutting feeds, conveyor belt speeds, and travel speeds are provided for all types of work. The 12A digs anything short of solid rock, working in any terrain.

Bulletin 46, just published, gives specifications and further facts.

Cellar Control Gates

SIMPLICITY, increased strength, new sealing efficiency, and heavier ram construction are given as features of the Type 38 Cellar Control Gate by



Interior view looking downward through Shaffer Type 38 cellar control gate equipped with Type 40 self-centering rams

Shaffer Tool Works, Brea, California, for control of drilling wells. The gate is provided with Type 40 self-centering rams for closing around pipe or with Type 40 rams for complete shut-off. These new gates retain all the salient features of previous designs of Shaffer cellar control gates and meet the requirements of latest drilling practice, the manufacturers state.

The Type 40 self-centering rams center small size drill pipe in the bore of the gate. These improved rams are made with protruding angular guides alternately top and bottom and as the rams move toward their closed position these angular guides engage the drill pipe and move it into central position in the ram. The guides telescope into the opposite ram block, which permits the abutting faces to seal perfectly. Ram rubbers may be either rubber or neoprene.

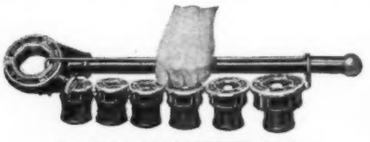
By using these new gates the seal can be effected against both the top and bottom inside faces of the gate body or the equipment can be supplied with the seal against the top inside face only and the bottom inside face provided with channels for sand drainage.

As the rams are moved to the closed position the abutting rubber faces of the ram blocks are stopped. The ram block holders continue their movement and the circular band of rubber around the ram blocks is compressed by the inward movement of the ram block holders and thus extrudes this band of rubber against the upper and lower inside faces of the gate body as well as forming a perfect seal around the pipe.

Additions to Ridgid Line of Pipe Tools

LATEST additions to the Ridgid line of pipe tools made by The Ridge Tool Company of Elyria, Ohio, are five new ratchet and three-way threaders for small pipe.

Nos. OOR, OR and 11R are of new, stronger design in all-steel malleable-alloy. They thread ⅛-in. to 1¼-in. pipe. Separate sets of semi-high-speed tool steel chaser dies are accurately cut, easily removed for regrinding. In No. OOR, die heads are quickly locked in or removed by a pull of the ratchet knob. In Nos. OR and 11R die heads push out easily for changing, snap into ratchet ring from either side, can't fall out, the manufacturer asserts. Electrical conduit dies are supplied at regular die prices. No special dies are needed for threading pipe close to wall; it is only necessary to turn the dies upside-down and shift to positions marked on die-heads. A carrier, which conveniently holds the ratchet ring and set of dies, is supplied with all complete sets at no extra cost.



No. OR and 11R RIDGID Ratchet Threaders for ⅛" to 1¼" pipe.

No. 30-A and 31-A 3-way Ratchet Threaders for ⅜" to 1" pipe.

The Series Nos. 30A and 31A three-way threaders for small pipe have virtually the same features as the series described above. They are compact, have double ball-end handles, and thread pipe from ⅜ in. to 1 in.

Distribution of these tools is exclusively through wholesale supply houses.

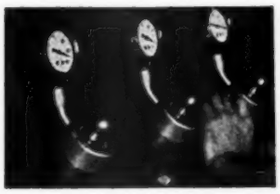
26 THOUSAND TIMES A DAY!

That's the number of times a ball rises in the cage of a deep well plunger pump and comes down *smack* on the valve seat. The seal must be perfect at every stroke for silently and unseen your pump lifts oil according to the quality of its valve seats and balls. Axelson's precision manufacture together with high quality materials accounts for the non-slip seal that gives long productive life and low-cost lifting.

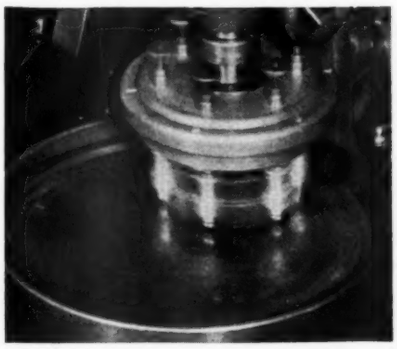
AXELSON MANUFACTURING COMPANY

Los Angeles St. Louis New York Tulsa

Representatives and distributors in all principal fields throughout the world.



Every Axelson Seat and Ball Assembly is individually tested under a practically perfect vacuum.



Axelson Seats and Balls are individually lapped in this Axelson designed and patented machine.

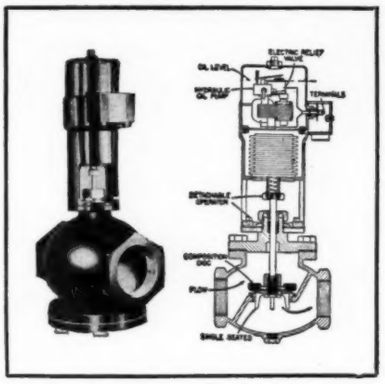
AXELSON

SELLS AND *SERVICES* DEEP WELL PLUNGER PUMPS AND SUCKER RODS

General Controls Company's Hydramotor Valve

ANNOUNCEMENT is made by General Controls Company, Glendale, California, of the General Controls Hydramotor Valve, a new all-purpose hydraulically operated motor valve, for handling air, gas, water, oil (any gravity, any grade), brine, saturated steam, etc.

The new valve is of the full-ported, single-seated type and affords 100 percent shut-off in any position, the manufacturer states. The electric pilot valve has a simple, two-wire, current failure control, with exceptionally low current consumption—only 60 va.



during the opening cycle and 5 va. when open. No gears are used and there is only one internal switch. There are a minimum number of moving parts, all of which are bathed in oil. The entire operating mechanism is detachable from the valve body.

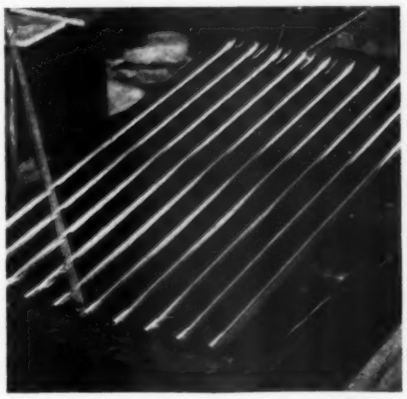
The valve itself is normally closed; application of current opens the valve. Approximate opening time is 45 sec.; approximate closing time, 10 sec.

Because of the numerous services in which this valve may be used, composition disks in the valve body are supplied to suit the service. Style "F" disk is for air, brine, butane and natural gas, light oils, and water of temperatures not exceeding 125°F. Style "H" disk is for steam to 150-lb. pressure and temperature not exceeding 400°F. Style "L" disk is for hot water to 250-lb. pressure and temperature not exceeding 250°F., and for steam to 25 lb.

Hydramotor valves are regularly supplied in IPS valve sizes of ½ in. to 1½ in. with brass body, bronze trim, and 2 in. to 4 in. with iron body, bronze trim; the 4 in. size has flange connections optional.

Full details and specifications may be had by writing the manufacturers, General Controls Company, at 700 West Ivy Street, Glendale, California.

26 THOUSAND TIMES A DAY!



That's the number of strokes—plunger against liner—metal to metal—week after week—month after month—that are encountered in ordinary deep well plunger pumping. That is the kind of treatment to which Axelson Plungers are subjected and for which they are fitted. The extra attention Axelson gives to details accounts for the extra performance and efficiency of Axelson Plungers in service.

AXELSON MANUFACTURING COMPANY

Los Angeles St. Louis New York Tulsa

Representatives and distributors in all principal fields throughout the world

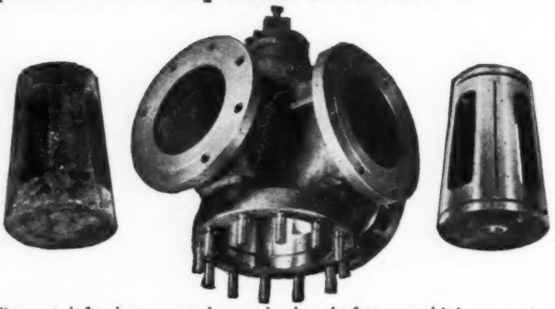
In the final inspection Axelson Plungers are repeatedly checked for surface finish, straightness, and A.P.I. tolerances.

Complete stocks of Axelson Plungers insure rapid service to the industry.

AXELSON

SELLS AND SERVICES DEEP WELL PLUNGER PUMPS AND SUCKER RODS

Valve Development for Temperatures to 1000° F



View at left shows merchromed plug before machining; center view, body; at right, plug after machining

AFTER more than two years of factory and field testing, a new valve application is announced. An unusual process known as Merchrome coating has been developed by Merco Nordstrom Valve Company. It permits a lubricated plug cock valve to handle services successfully where the temperatures run as high as 1000°F., according to Nordstrom engineers.

Although the use of Merchrome-coated valves is principally for refineries on hot oil and vapor lines, such as cracking, coking and topping units, and for mud lines to combat abrasion and erosion, the Merchrome application is expected to gain wide acceptance in chemical plants and in industries where stainless steel valves have limitations, according to the manufacturer.

The Merchrome coating process is a development in which a welded coating is applied to the rotating surfaces of the plugs and bodies and in some cases other parts of the valves. This coating is a complex metal alloy of extreme hardness and is corrosion-resistant. Another invaluable characteristic of this coating is said to be its extremely low coefficient of friction. The hardness of Merchromed surfaces is approximately 54 on the Rockwell C Scale and this alloy has the property of maintaining this hardness practically unimpaired at temperatures of 1000°F., it is stated.

The corrosion resistance of the Merchrome coating is approximately equal to that of the stainless steels and for this reason it makes an ideal solution of the problem of preventing the galling and scoring of the sliding surfaces of a stainless steel plug cock without sacrificing its resistance to corrosion, it is stated. The Merchrome is said to form an inseparable bond that may be applied in any thickness. In services where stainless steel valves such as the KA2S variety are required, the Merchrome coating makes this practicable for the higher temperatures and pressure services, such as in the chemical industry, as well as for refinery service, the makers assert.

Another interesting development is included. For high-pressure service these valves are "hot-lapped." The plugs are lapped under heat into the bodies at the temperature corresponding to the service for which they are intended. This provides a means of obtaining an extremely accurate fit between the plugs and bodies at the operating temperature and insures extremely smooth operation, it is said. The valves are tested before shipment with hot oil at temperatures to 600°F., and under a pressure equivalent to the intended operating pressure.

A new bulletin describing Merchromed valves may be obtained by writing to Merco Nordstrom Valve Company, 400 Lexington Avenue, Pittsburgh, Pennsylvania.

Axelson Casing Pumps and Packers; Top-Lock Hold-Down

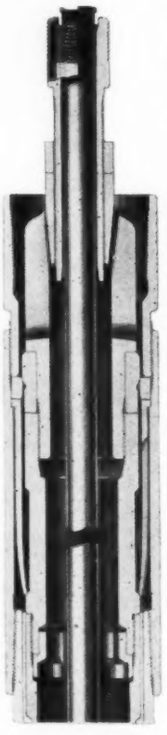
AN ADDITION to the Axelson line is the Axelson Casing Pump and Packer Assembly, a patented two-unit arrangement that uses standard Axelson pumps. Standard parts and A.P.I. connections have been used throughout.

When first put into service, the lower unit, which comprises the anchoring device and the packer, is run into the well and set by means of the rod string. An inexpensive setting tool is used in conjunction with the cast-steel setting collar incorporated in the lower unit. The depth at which the unit is set is easily controlled, and the operation is essentially the same as setting a tubing anchor.

After the packer has been located, the rods are withdrawn, the setting tool is removed, and the pump is then run in on the rods. Seating is obtained by forcing the tapered seating cone on the bottom of the pump into the neoprene packer. This expands the packer cup into contact with the casing, packing-off the casing and seating the pump.

To pull the pump it is not necessary to disturb the packer or the anchor as the lower unit remains in the well. To change the location of the packer it is only necessary to run in the setting tool, release the anchor, and move the packer to the new position.

Another item of Axelson equipment is the top-lock hold-down that allows a stationary type rod pump to be suspended entirely from its upper end. This obviates the possibility of sand packing between the pump and tubing, and facilitates removal of the pump, while providing positive anchorage by means of the heat-treated spring-prong lock, the manufacturer asserts.



Top-lock hold-down

Renewable hardened and ground seating elements are provided that can be easily serviced or inexpensively replaced. The rod guide is adjustable to allow accurate spacing of the plunger travel.

A portion of the tubing immediately below the hold-down shoe is perforated and a suitable length of tail pipe is used below the pump for the effective separation of oil and gas.

This equipment is manufactured by the Axelson Manufacturing Company, Los Angeles, California.

Timken's Bearing Series

THE Timken Roller Bearing Company, Canton, Ohio, has put into production a new bearing series of the standard "SS" type. The first bearing in this series is 9285-9220, with a cone bore of 3 in., O. D. of 6⅜ in. and width of $1\frac{15}{16}$ in. At 500 r.p.m. this bearing has a radial capacity of 6255 lb., and a thrust capacity of 8710 lb. The 9100, 9300, and 90000 series bearings of the "SS" type have also been redesigned to reduce the outside diameters and widths of each series while still maintaining the same load-carrying capacities. Two cone bores of $2\frac{7}{16}$ in. and $2\frac{11}{16}$ in. are available in the 9100 series. Two different bores of 3 in. and $3\frac{5}{16}$ in. are available in the 9300 series and one cone bore of $3\frac{3}{16}$ in. in the 90000 series.

These series in addition to those now available in the "SS" type provide a wide range of capacities, varying in cone bores from ¾ in. to 12½ in. The "SS" series are single row bearings with steep cup and cone angles. They are designed primarily to handle those loading conditions where thrust loads are large compared to the radial loads.

Durametallic Oil Pressure Unit

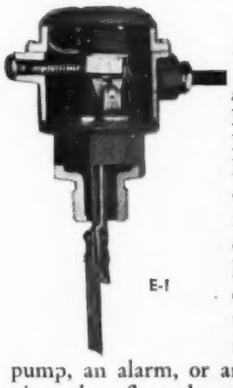
THE NEW Durametallic Oil Pressure Unit, manufactured by the Durametallic Corporation, 2104 Factory Street, Kalamazoo, Michigan, is a compact, positive-action unit designed to supply lubricating oil at a uniform pressure. It is utilized to circulate lubricating oil through stuffing boxes, large bearings, to hydraulic equipment, to heat-treating systems, etc.; in brief, wherever there is a need for circulating

or supplying oil at a uniform pressure to 1000 lb. Other fluids also can be handled, such as soluble oil emulsions, fuel oil, kerosine, gasoline, and naphtha, but at lower pressures than lubricating oil.

The complete unit consists of base, motor, coupling, tank, gasketed lid, manual pressure regulator, cooling coil, filter, pressure gauge, oil level gauge, tank filler inlet, vent connection, and drain valve, all assembled, tested, and ready to connect.

Additional information can be obtained from the manufacturer.

McDonnell Flow Switch



A SIMPLE new flow witch has been announced by McDonnell and Miller, Wrigley Building, Chicago, Illinois, manufacturers of boiler water level controls. It employs a positive mechanical action to start a pump, an alarm, or any electrical device when flow through a pipe starts or stops.

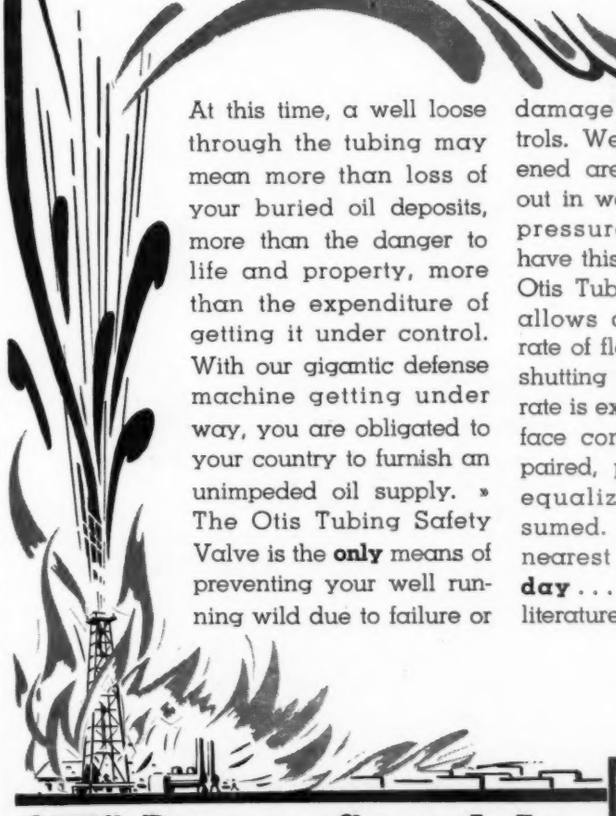
Known as the No. E-1, the McDonnell flow switch consists essentially of a long flexible paddle that is extended into the pipe. When this paddle is forced backward by the flow in the pipe it closes an electric circuit and thus starts whatever machinery or valves the switch controls. When flow through the pipe stops, the paddle returns to normal position, breaking the electric circuit. Reverse acting switches are available too; these break the electric circuit when flow starts and complete it when flow stops.

The paddle itself is very flexible—will easily pass stones and debris and will not interfere with high rate flows. It can be cut to any length to fit every size of pipe. The paddle arm is connected to the electric switch through a flexible metal bellows that keeps the switch absolutely waterproof, the manufacturer asserts. Tension of this paddle can be varied by means of an adjusting spring. Top cover of the switch is removable to provide access to all moving parts.

The manufacturer will be pleased to supply further information or a copy of the newly prepared catalog sheet, L-17, which illustrates the construction of this flow switch.

NO MORE RUNNING *Wild*

OTIS TUBING SAFETY VALVE IS A *Sure Safeguard* AGAINST DISASTER



At this time, a well loose through the tubing may mean more than loss of your buried oil deposits, more than the danger to life and property, more than the expenditure of getting it under control. With our gigantic defense machine getting under way, you are obligated to your country to furnish an unimpeded oil supply. » The Otis Tubing Safety Valve is the **only** means of preventing your well running wild due to failure or damage of surface controls. Wells in war-threatened areas, in townsites, out in water and all high pressure wells should have this protection. » The Otis Tubing Safety Valve allows a predetermined rate of flow, automatically shutting the well in when rate is exceeded. After surface connections are repaired, pressures can be equalized and flow resumed. » Write or call nearest Otis office . . . **today** . . . for descriptive literature.

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OTIS Pressure Control, Inc.

DALLAS, TEXAS

Division Offices: Houston, Oklahoma City, Hobbs
Export Office: 74 Trinity Place, New York, New York, U.S.A.
Representatives:
Otis Eastern Service, Inc., Wellsville, N. Y.; Western Pressure Control, Inc., Los Angeles, Calif.

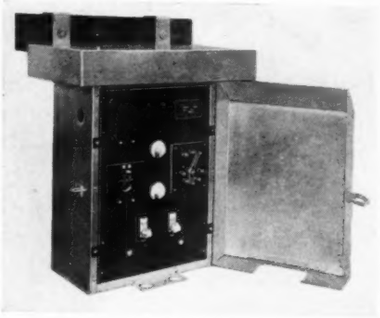
Rexselen Cathodic Corrosion-Eliminator

THE Rexselen Cathodic Corrosion-Eliminator is a complete rectifier and control assembly especially designed for cathodic protection of pipe and embodies Selenium Rectifier Stacks.

The efficiency of Rexselen Eliminators is said to be high under all practical conditions of loading, power efficiency ranging between 60 and 80 percent, depending upon the voltage and current output. An important feature is that high efficiency is sustained throughout the long life of the rectifiers as only a slight increase in forward resistance occurs during the first 10,000 hr. of operation, after which no change takes place, it is stated.

The Type CB Rexselen Corrosion-Eliminator illustrated is rated at 8 v., 50 amp. d-c. and is for operation on single-phase a-c. supply. It measures only 28 in. high, 21 in. wide, and 15 in. deep, and weighs 110 lb. Other Type CB units are available in higher and lower current capacities from 20 to 200 amp. and also in higher voltage ratings. The 8-v. units can be adjusted by means of transformer taps to a d-c. output as low as 0.7 volt. The higher voltage units can be adjusted to less than one-half full-rated voltage.

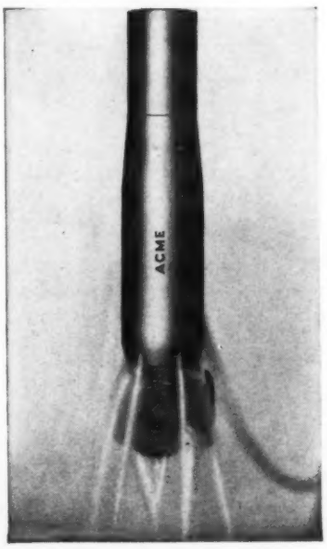
The control panel of the Eliminator is equipped with a-c. magnetic circuit breaker with time delay, ammeter, and voltmeter, tap-changing link switch, and solderless d-c. terminals. The new Type CB Eliminators are equipped with



the Thermotrol, an exclusive device for the protection of the unit against damage due to overloading or operation in abnormally high air temperatures. The rectifier and auxiliary equipment are built as a unit and mounted in a ventilated weatherproof steel cabinet designed for out-of-door mounting on a pole or wall. Indoor models also can be supplied.

The equipment is manufactured by Electrical Facilities, Inc., 4224 Holden Street, Oakland, California.

Acme Mud Collar

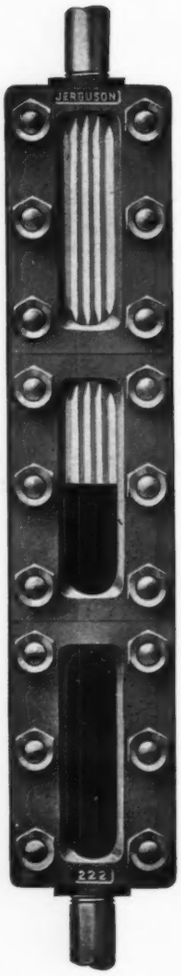


Mud collar in action

THE Acme Mud Collar, recently introduced by Acme Fishing Tool

JERGUSON

REFLEX GAGES



are preferred by the Oil Industry because of their reputation for maximum efficiency at all temperatures and pressures.

Easy to read because the . . . .

EMPTY SPACE SHOWS
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LIQUID LEVEL APPEARS
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Ideal for tanks, towers, stills, etc., carrying gasoline, kerosene, oil, no matter what the color of the liquid. Furnished with or without valves for every type of service.

When you need to show the color and density of liquids, use Jerguson Transparent (thru vision) Gages.

Jerguson Gages are Best
By every real test.

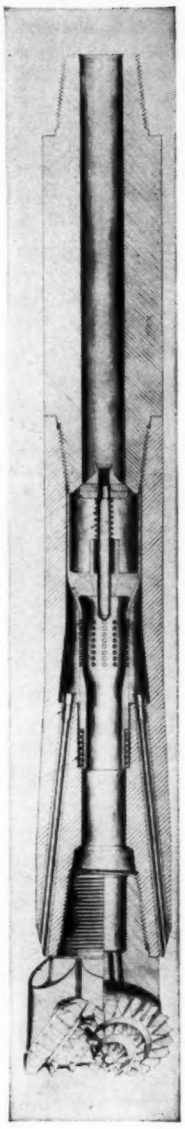
Write for Catalog.

JERGUSON GAGE & VALVE CO.

89 FELLSWAY

SOMERVILLE MASSACHUSETTS

Company, Parkersburg, West Virginia, is designed to eliminate "mud rings" and "balled up" bits, and to reduce the possibility of costly fishing jobs.



Cross-sectional view of the mud collar

The tool is used between the rotary bit and drill collar and consists of a collar and rotary tool joint in which is housed a fluid "cylinder" from which six pressure streams are diverted to the outside of the bit. The six fluid streams flow continuously over the outside of the bit, being forced through the tubes at a pressure of 200 to 1000 lb., thus keeping the bit clean under normal drilling conditions. Thus, the possibility of mud rings and "balled up" bits is virtually eliminated, the makers assert, as well as delays in pulling-out. A clean bit means faster, smoother, easier cutting, it is pointed out, resulting in better hole and less dragging and strain on the drill pipe.

Should it become necessary to make a cut-off the operator can cut within 26 in. of the bottom by using an Acme Mud Collar Float, thus leaving a minimum of iron in the hole and making it easier to work-over and fish-out.

Additional information concerning this equipment is available from the manufacturer.

Oxweld Nozzles for Oxy-Acetylene Gouging

A SERIES of new oxy-acetylene gouging nozzles, for use with a standard hand-cutting blowpipe, such as the Oxweld C-32 cutting blowpipe, has been announced by The Linde Air Products Company. These new Oxweld nozzles, which are available in three sizes, provide a means for quickly and accurately removing a narrow strip of surface metal from steel plate, forgings, and castings, the manufacturer states.

The nozzles are designed to deliver a relatively large jet of oxygen at low velocity. By proper manipulation of the blowpipe in which the nozzle has been inserted, a smooth, accurately-defined groove can be cut or gouged out of the surface of the metal. By using various standard size nozzles and manipulations, the groove can be varied in width and depth at the will of the operator.

Important uses for these new nozzles are: gouging the underside of electric welds; removal of weld metal, such as temporary tack-welds and defective welds; preparation of plate edges for welding, and maintenance and scrapping operations. A wide field of miscellaneous uses includes gouging in metal-shaping and trimming processes.

Further information about the new Oxweld gouging nozzles can be obtained from the nearest office of The Linde Air Products Company.

SAVE REPLACEMENTS...
REDUCE DRUM WEAR...

ASBESTOS "CABLES" form the backbone of J-M 420 Rotary Lining. Woven into a compact mass, impregnated and compressed, they make a remarkably efficient and durable lining for heavy-duty work.

WITH THIS *TOUGHER*
ROTARY LINING

● Most drillers and owners alike are sold on the better braking performance of J-M 420 Rotary Lining. Made of a specially impregnated, improved weave of "cabled" asbestos fibers, this new-type material is unusually strong and durable . . . highly resistant to heat and shock. It lasts longer, requires fewer replacements. Feed-off is unusually even, load control is easy and sure. Rim scoring is practically eliminated. It will pay you to get full details on J-M 420 before your next relining job. Write Johns-Manville, 22 East 40th Street, New York, N. Y.

JM Johns-Manville
420 ROTARY LINING

Unitized Rotary Slips

DESIGNED to combine extreme lightness for easy handling and full strength with a large safety factor for suspending the longest strings of drill pipe, a new unitized type of rotary slips, designated the Type "C-U," is being introduced by Baash-Ross Tool Co., 5512 Boyle Avenue, Los Angeles, California.

The Baash-Ross Type "C-U" rotary slips consist of 3 heat-treated, alloy-steel body sections joined together by means of an unusual flexible hinge and equipped with long, readily replaceable liners, and 3 solid steel safety loop handles.

The 3 body sections are joined together to insure that all will set at the same level in the master bushings when

supporting the drill-pipe load, in order to eliminate any tendency to crush the pipe. The flexible hinges that join the body sections permit them to become automatically adjusted laterally and vertically as the pipe load is brought to rest, so that the pipe is gripped evenly by the liners.

Increased operating convenience of the new Baash-Ross Type "C-U" rotary slips is said to result from the lightness in weight obtained by coring all excess metal from the body sections and by the correct balance resulting from the manner in which the handles are attached to the body sections. The slips stand firmly without tipping when resting on the rotary table, when the drill pipe is being run in or pulled out of the hole. The solid steel handles are hinged to the body sections so that they lie flat upon the rotary table out of the way of the elevators and are provided with large, solid steel safety loops to protect the hands of the worker. Type "C-U" rotary slips are so designed that one body size accommodates interchangeable liners to fit from 4 to 6 or more different sizes of pipe.

An improved method of retaining the liners in the body sections is employed, according to Baash-Ross Tool Company. Two liners are placed vertically in dovetailed slots on the sides and at the bottom of each body section. The long T-head key, inserted from the top of the body, fits vertically between the liners in the slot in the body and holds them securely in position. Although this method insures that the liners cannot become accidentally loosened from the body even though they may be broken, it makes changing of the liners in the field an easily accomplished operation and no special tools are required, it is stated.

A new bulletin completely describing the Baash-Ross Type "C-U" rotary slips is available.

Strength plus Flexibility

Grizzly Pressure Seal Rotary Hose is a remarkable combination of steel and rubber—*strength and flexibility*. Heavily steel armored throughout its entire length, it actually embodies the full strength of this steel — *more than ample* to withstand without injury *higher pressures* than might be developed under *any drilling conditions*. Its extraordinary flexibility, obtainable only by the exclusive Grizzly method of fabrication is clearly shown by the illustration below—a 50-foot length of Grizzly 3-inch rotary hose snaked out on the shipping room floor where the adapter is to be installed and the complete unit prepared for shipment. Note there is no kink or strain at any point throughout the entire 50-foot length . . . This extraordinary *strength plus flexibility* is your assurance against hose troubles, frequent repairs and replacements, and excessive hose costs. Ask your supply dealer, or write direct for more detailed information.

The Grizzly Pressure Seal Coupling—one of the important developments in rotary hose engineering—eliminates leaks at any pressure, cutting out of nipples, and coupling troubles. For detailed construction features, write for Bulletin No. 20-OF.

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GRIZZLY PRESSURE SEAL ROTARY HOSE

New Eastman Oil Well Survey Bulletin

Eastman Oil Well Survey Company, Dallas, Texas, and Long Beach, California, has completed a brochure giving full description, information and instructions for operating the Type-M Drift Indicator. The bulletin is No. 401.

New Firm Formed

The firm of Parker, Foran, Knode and Boatright has been dissolved. E. V. Foran, W. F. Knode, Byron B. Boatright, and P. C. Dixon have announced the formation of a partnership to operate as consulting petroleum and natural gas engineers under the name of Foran, Knode, Boatright and Dixon. Headquarters are in the Second National Bank Building, Houston, Texas.